Effort-reward-imbalance, overcommitment and employee's health: Testing the validity of the ERI model

Thesis

presented to the Faculty of Arts of the

University of Zurich

for the degree of Doctor of Philosophy

by

Daniel Preckel

of Germany

Accepted on the recommendation of

Prof. Hans Joachim Haug, MD

PD Joachim Fischer, PhD MD

Zurich, 2005

ACKNOWLEDGEMENTS

This thesis is based on a project termed "work and health" and was initiated by the Institute of Behavioral Sciences at the Swiss Federal Institute of Technology (ETH). It was undertaken in co-operation with the European Aeronautic Defense and Space Agency (EADS). The effort-reward-imbalance model proposed by Siegrist (2002) provides the underlying theoretical framework. The general aim of this thesis was to test the predictive validity of this model in respect to a wide range of biological and psychological markers of employees' health.

I would like to express my gratitude to the following people.

I thank Prof. Dr. Karl Frey for providing the opportunity to carry out a stimulating research in a supportive environment. I thank my mentors, PD Dr. Joachim Fischer and Prof. Dr. Roland von Känel, for their continuous and thoughtful support and guidance. I particularly appreciate the way in which they have put their faith in me and my work.

Alessandra Acciarito, io ti ringrazio per avermi supportato e accompagnato durante questi eccitanti ma stressanti due anni che noi abbiamo trascorso a Zurigo in Svizzera. Ti ringrazio di riempire la mia vita con il suo vero significato; l'amore e la gioia.

Zurich, 16 December 2004

Daniel Preckel

CONTENT

1 LIST OF ABBREVIATIONS

BMI = Body mass index

CAD = Coronary artery disease

CVD = Cardiovascular diseases

CRP = C-reactive protein

DHEA-S = Dehydroepiandrosterone sulfate

EADS = European Aeronautic and Defence Company

ERI = Effort-reward-imbalance

ETH = Swiss Federal Institute of Technology

Hb1Ac = Glycosylated hemoglobin

HDL = High density lipoprotein

HPA axis = Hypothalamic-pituitary-adrenal axis

HrQoL = Health-related quality of life

LDL = Low density lipoprotein

MI = Myocardial infarct

OC = Overcommitment

OR = Odds ratios

RR = Relative risks

SES = Socio-economical status

SEM = Standard error of mean

SD = Standard deviation

SAM axis = Sympathetic-adrenal-medullary axis

VE = Vital exhaustion

2 ABSTRACT

Background: The effort-reward-imbalance model, originally formulated by Johannes Siegrist, has received considerable attention in occupational health research. It has predictive power for several adverse health outcomes, from psychosomatic complaints to cardiovascular diseases. This model defines stressful experiences at work as an imbalance between high effort and low reward – a combination that can be aggravated by a particular individual coping style, namely overcommitment. To date, several questions pertaining to the model have yet to be fully investigated: The relation between effort-reward-imbalance and overcommitment to the mental state of vital exhaustion – a state characterized by unusual fatigue, irritability, and demoralization and an established predictor of coronary heart disease; the hypothesis that effort-reward-imbalance and overcommitment interact synergistically as risk factors to the detriment of health outcomes; the physiological mechanisms that mediate the association between the model and health outcomes; and, the factorial validity of the current ERI model.

Aims: General aim of this thesis was to evaluate the predictive and internal validity of this model in terms of a wide range of biological and psychological markers of employees' health. Briefly, aims were to (1) examine the relationship between effort-reward-imbalance and overcommitment to vital exhaustion, (2) to evaluate the current model on the basis of the interaction hypothesis that suggests that the effect of effort-reward-imbalance is moderated by overcommitment, (3) to examine the relationship between effort-reward-imbalance and overcommitment to allostatic load, and (4) to evaluate the model according to its underlying factorial structure.

Participants and Methods: All studies are conducted as cross-sectional studies. Study I is based on a stratified random sample of 642 employees (mean age 39.9 years, standard deviation 10.7 years; 89.6% male) from a manufacturing and assembly plant for airplane parts in Southern Germany. Among others, participants completed the nine-item shortened Maastricht Exhaustion Questionnaire and Siegrist's Effort-Reward-Imbalance questionnaire. Study II is based on a sample of 1894 employees (mean age 39.7, SD 11.86 years; 86.8% male) from two separate production plants in the airplane manufacturing industry in Southern Germany. Several indices of self-reported health and well-being were assessed by standardized questionnaires regarding health-related quality of life, depressed mood, vital exhaustion, and sleep quality. Study III is based on the data of 1588 employees (mean age 39.1 ± 11.7 years; 87 % male) of the same population of industrial workers as study II. To examine the relationship between effort-reward-imbalance and overcommitment to allostatic load, 15 indices of allostatic load were measured: body-mass index, waist-hip ratio, systolic and diastolic blood pressure; leukocytes, glycosylated hemoglobin, high density lipoprotein-cholesterol, low density lipoprotein-cholesterol, C-reactive protein, fibrinogen, D-dimer, dehydroepiandrosterone sulfate; albumin, urinary cortisol, norepinephrine, and norepinephrine. The sample for study IV is also drawn from the same population as in study II. To evaluate the underlying factorial structure of the current ERI model, four alternative models were fitted using the structural equation approach.

Results: Study I: 51% of variance in vital exhaustion could be explained by a multivariate regression model that included Type D-personality, overcommitment, depressed mood, SALSA decision authority, effort-reward-imbalance, and adverse physical conditions. In reference to the ERI and SALSA model, overcommitment was revealed as the best predictor for vital exhaustion, explaining 27% of the variance of vital exhaustion. Study II: Employees reporting high effort-reward imbalance or high overcommitment exhibited decreased health-related quality of life and higher risk of sleeping problems, vital exhaustion, and depressive mood (standardized beta coefficients ranged from |0.22| to |0.49| SD) as compared to non-burdened controls. The combination of high effort-reward-imbalance and overcommitment constituted a high risk condition that was associated with the highest deviations in health outcomes (SD ranged from |0.46| to |1.14|). This constellation particularly predicted vital exhaustion (1.11 SD), depressed mood (0.94 SD), and SF12 mental health (0.90 SD). Study III: Adjusted analysis controlling for age, gender, alcohol intake, smoking, and physical activity revealed that subjects reporting high ERI imbalance and high overcommitment had significantly higher waist to hip ratio (beta coefficient = 0.02), increased diastolic blood pressure (beta = 1.54 mm Hg), higher levels of low density cholesterol (beta = 6.56 mg/dl), higher WBC (beta = 0.38 cells/mcl), elevated C-reactive protein (beta = 0.18 mg/dl), urinary albumin (beta = 0.17 mg/l) and overnight epinephrine excretion (beta = 0.15) as compared to the reference-group with effort-reward balance and low overcommitment. Study IV: Confirmatory structural equation modeling supported the factorial validity of a model with effort and reward subscales as well as a model encompassing the full theory (including overcommitment). A three-factor structural model corroborated the theoretical concept that there are three different types of rewards (esteem, security, money). The model fit substantially improved by using three new subscales, which differentially assigned items of reward compared to the original conceptualization (delta chi-square = 774, df = 3, $p < 0.001$), thus providing excellent fit (GFI = 0.95, CFI = 0.93, RMSEA = 0.057). The new subscales are labeled: esteem, security, and gratification.

Conclusions: Study I: Overcommitment, indicating an exhaustive work-related coping style, is independently associated with vital exhaustion. It appears to be an important personality trait that may contribute to feelings of exhaustion at times of increased job strain. Study II: The findings highlight the predictive validity of the effort-reward model for employees' health. Although the cross-sectional design does not allow conclusions as to causality, the data suggests that the additional effect of effort-reward imbalance paired with overcommitment represents the strongest risk factor for poorer self-reported health considered in terms of health-related quality of life, sleep problems, vital exhaustion and depressed mood. Study III: The interaction of ERI imbalance and overcommitment emerges as a risk factor for multiple biological deviations, particularly increased inflammatory activity. Study IV: Using revised subscales for the reward component, the observed data from a large sample of industrial employees confirms the factorial structure of the current ERI-overcommitment model.

In general, the studies reported in this thesis demonstrate that the effort-reward-imbalance model provides important measures for the evaluation of an adverse working environment. Its predictive validity is high for various psychological health outcomes, such as vital exhaustion, self-reported quality of life, depressed mood, and indicators of allostatic load. The model has high reliability and factorial validity. Not only do the reported findings generally correspond with previous findings, the new findings also broaden our understanding of the key role played by critical psychological factors in adverse working environments for employees' health. It is recommended that the ERI is applied as a validated and economical instrument to screen and improve workplace conditions.

Keywords: Effort-reward-imbalance, self-reported health, allostatic load, factorial validity.

3 INTRODUCTION

Research conducted into the causes of coronary heart disease has identified chronic work stress as a psychosocial factor that contributes significantly to the pathogenesis of cardiovascular diseases (Hemingway & Marmot, 1999; Krantz & McCeney, 2002; Rozanski, Blumenthal, & Kaplan, 1999). In the past decades, specific conditions of chronic work stress and their impact on physical health were examined with the help of different theoretical models (Karasek & Theorell, 1990b; Levi, Bartley, Marmot, Karasek, Theorell, Siegrist et al., 2000; Semmer & Mohr, 2001; Siegrist, 2002b). Two models identifying stressful components of the psychosocial work environment have received particular attention: the job strain model (Karasek, 1979; Karasek & Theorell, 1990b) that posits that the possibility to control the work situation is crucial to workers' health, and, more recently, the effort-reward-imbalance (ERI) model (Siegrist, 1996) that suggests that reciprocity between effort / reward and overcommitment to work are central concepts in determining health and well-being. Since its introduction by Siegrist in 1986, the ERI model has gained considerable attention especially in European research, and numerous studies have applied the model to various health outcomes (Siegrist, 1986; Siegrist, 2002b; van Vegchel, de Jonge, Bosma, & Schaufeli, 2004).

The ERI Model highlights the idea of a reciprocal exchange between efforts (psychological and physical demands at work) and rewards (salary, esteem, and job security). It postulates that failed reciprocity between efforts and rewards ("effort-reward-imbalance") may enhance the activation of the autonomic nervous system and influence the risk of coronary heart disease (Siegrist, 1996, 2002a; Siegrist & Peter, 1996). According to the model, adverse health effects can also be triggered by an individual's exhaustive coping style, known as overcommitment. This coping style might aggravate the negative consequences of effort-reward-imbalance by impairing health. One characteristic of the ERI model is the explicit distinction between a situational component regarding the work environment, and a personal component regarding attitudes, behaviours and emotions.

During the past 10 years, numerous studies have collected evidence corresponding to model´s hypotheses, particularly in predicting the occurrence of coronary heart disease (Bosma, Peter, Siegrist, & Marmot, 1998; Kivimaki, Leino-Arjas, Luukkonen, Riihimaki, Vahtera, & Kirjonen, 2002; Kuper, Singh-Manoux, Siegrist, & Marmot, 2002), but also in predicting psychosomatic complaints (e.g., (Niedhammer, Tek, Starke, & Siegrist, 2004; Stansfeld, Bosma, Hemingway, & Marmot, 1998) and depression (Godin & Kittel, 2004; Pikhart, Bobak, Pajak, Malyutina, Kubinova, Topor et al., 2004; Tsutsumi, Kayaba, Theorell, & Siegrist, 2001; Watanabe, Irie, & Kobayashi, 2004)). Despite the growing number of publications there is still a paucity of knowledge concerning the following scientific questions:

- The relationship between effort-reward-imbalance and overcommitment to vital exhaustion, the latter being a risk factor for cardiovascular disease (Appels & Mulder, 1988; Cole, Kawachi, Sesso, Paffenbarger, & Lee, 1999; Kop, Appels, Mendes de Leon, de Swart, & Bar, 1994);
- The relative contribution of the model's components, that is, effort-reward-imbalance and overcommitment, to the risk of adverse health outcomes;
- The pathophysiological mechanisms through which effort-reward-imbalance or overcommitment might increase the risk for future disease; and,
- The factorial structure of the recently used ERI model.

Against the background of these unanswered questions, the aims of the present thesis were to investigate the recent effort-reward-imbalance model (Siegrist, 1999) in four different aspects:

- The first study (I) assessed the model's ability to predict vital exhaustion. The aim of that study was to analyze the relationship between overcommitment and exhaustion. So far, no study has shown that there is a relationship between exhaustion and OC.
- The second study (II) analyzed the predictive validity of the ERI model with particular focus on the interaction between effort-reward-imbalance and overcommitment. As external criteria a set of indicators for psychological health were used: Vital exhaustion, health-related quality of life, depressed mood, and sleep problems.
- In the third study (III) the aim was to validate the ERI model on physical health, and to further elucidate potential pathways linking effort-reward-imbalance and overcommitment to adverse biological health indicators. Although several potential pathways have been proposed (Irie, Tsutsumi, Shioji, & Kobayashi, 2004; Peter, Alfredsson, Hammar, Siegrist, Theorell, & Westerholm, 1998; Peter & Siegrist, 1997; Siegrist, Peter, Cremer, & Seidel, 1997; Steptoe, Siegrist, Kirschbaum, & Marmot, 2004; Vrijkotte, van Doornen, & de Geus, 1999) little is understood about the pathophysiological mechanisms of the ERI model (van Vegchel, de Jonge, Bosma et al., 2004). Physical health was operationalized following the framework of allostatic load previously proposed by McEwen (McEwen, 1998a). Until today, the concepts of allostatic load and effort-reward-imbalance have not been examined in relation to one another.
- In the fourth study (IV) the factorial structure of the current ERI model was tested by using a structural equation modeling approach. To the author's knowledge, a factorial validation of the current ERI model (Siegrist, 1999) has not been published in the literature.

Briefly, the core of this thesis was to extensively test the current ERI model in relation to psychological, biological, and methodological criteria. The data presented here were obtained from employees of two separate production plants in the airplane manufacturing industry of the EADS in Southern Germany. The data collection was realized in 2000-2003.

The thesis' presentation is organized as following: The introduction briefly reviews selected general stress concepts and stressors at work. The following section reviews the stress research literature in organizations with specific emphasis on the role of effort-reward-imbalance and overcommitment, that is, the two core elements of the effort-reward-imbalance model that are the focus of the four research questions reported here. The chapter includes a more detailed presentation of the effects of ERI-related work stress in psychological health status of employees and cardiovascular risk factors. The next part gives a review over potential stress reactions. The fifth part of the introduction briefly reviews the allostatic load concept and illustrates its role in susceptibility to cardiovascular diseases. Subsequently, selected psychological stress reactions that are reported in the empirical studies are presented. Following the introduction, the data from the four sub-projects are presented in separate chapters, which contain detailed analyses of the relationships between the model's components and psychological biological measurements and health. The thesis is concluded with a general discussion of the results. After a brief summary of the obtained results, the research approach is reflected on and critically discussed. Subsequently, theoretical and practical implications of the results are given. The thesis concludes with an outline of future research directions. Three options for refining the ERI model are presented as they offer the most promising avenues for further research.

3.1 Definitions and concepts of stress

Definitions of stress

In the history of stress research, a number of definitions of stress have been developed by researchers (Kudielka & Kirschbaum, 2001). The term "stress" was first defined by Hans Selye (Selye, 1936). Based on extensive experimental research with rats, he described stress as the non-specific bodily response to demands placed on the body (Selye, 1974). Selye developed the concept of the general adaptation syndrome (GAS), a stereotyped physiological response to stress involving three progressive stages: The first stage, an *alarm-reaction stage*, is characterized by bodily response to psychological or physiological shock. In this stage a process of adaptation is promoted and homeostasis is restored by the release of epinephrine from the adrenal medulla and glucocorticoids from the adrenal cortex; the second stage is the *stage of resistance* characterized by adaptation, a process during the course of which the body learns to efficiently cope with the stressor, i.e. shrinking or atrophy of the thymus, spleen, lymph nodes, and the lymphatic system; and, finally, the *stage of exhaustion*, which ensues in the presence of too severe or long-term exposure to the same stressor.

In stress research, the cognitive perspective was first introduced by Richard S. Lazarus and colleagues. They pointed out that stressfulness experienced in connection with a stimulus is not a simple property of the stimulus alone but also a result of cognitive and emotional reactions by the organism to that stimulus (Lazarus, 1991; Lazarus & Folkman, 1984). In their transactional cognitive stress model they focused on the role played by the individual appraisal of a forthcoming stressor as well as the perceived capacity to deal with the stressor in order to explain interpersonal differences in stress responses (Lazarus, 1999) (Lazarus, 1991; Lazarus & Folkman, 1984). Stress is seen as the result of a transactional process that is set in motion when a person appraises a situation as taxing or exceeding the available resources or endangering well-being (Lazarus, 1999). The subjective cognitive estimation of a situation as challenging, threatening, harmful, or associated with loss ("primary appraisal") mediates between the stressor and the individual's stress reaction. In addition to the perception of environmental demands, personality characteristics and individual prior experiences as well as the subjective evaluation of the person's available resources ("secondary appraisal") influence how an individual copes with a certain stressor (Carver & Scheier, 1996; Lazarus & Folkman, 1984). Coping means "the cognitive, emotional and behavioral efforts of an individual to manage specific external or internal demands which are appraised as taxing or exceeding the resources of the person (Carver & Scheier, 1996), 141. Coping behaviors are conscious strategies used by the individual when confronted with particular stressful events.

Based on this cognitive model, a concept has been proposed by Levine and Ursin (Levine & Ursin, 1991; Ursin & Eriksen, 2004) that differentiates "stress" into four subclasses of "stress": (a) stress stimuli, (b) stress experience, (c) stress response, and (d) experience of the stress response. In this concept a stressor or stress stimuli (1, defined as load) is evaluated by the brain (2). This evaluation may result in a stress response (3, alarm) that is fed back (4) to the brain. The physiological stress response may lead to training or straining, depending on the type of activation. Phasic arousal is seen in individuals with a positive expectancy. Sustained arousal may lead to pathology (strain). The brain may alter the stimulus (5) or the perception of the stimulus, by acts or expectancies.

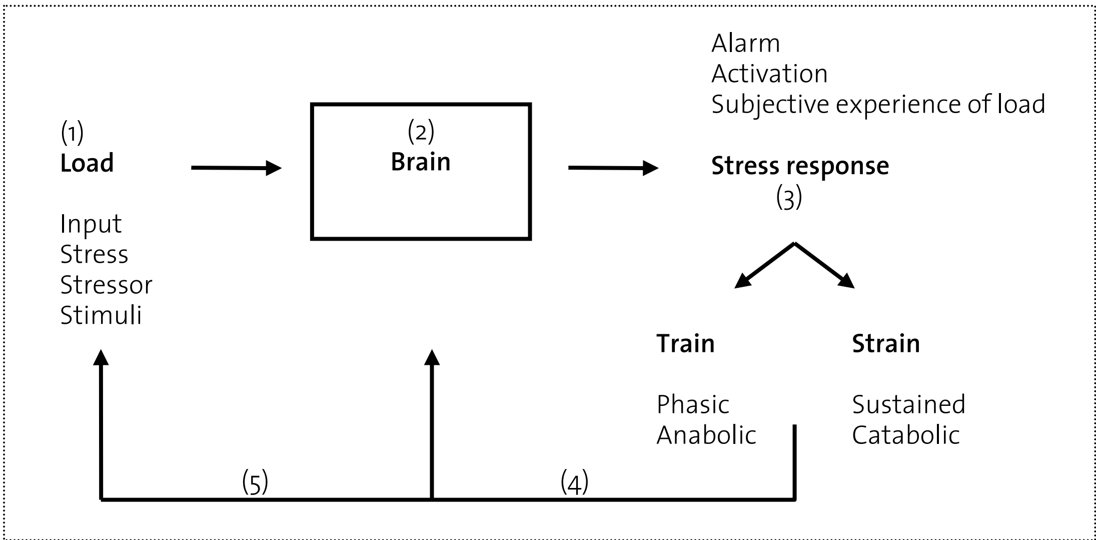


Figure 1: Stress concept by Levine and Ursin (Levine & Ursin, 1991)

Within the biological framework of Allostatic Load, which will be presented in chapter 3.5.2 in more detail, stress can be defined as a biological or perceived threat to the physiological or psychological integrity that results in physiological or behavioral responses (McEwen, 2000a). The body responds to these threats by producing hormonal and neurotransmitter mediators that set in motion physiological responses of cells and tissues throughout the body, leading to a coordination of physiological responses to the current circumstances (McEwen, 1998b). Not just dramatic threats, but the many events of daily life elevate the activities of physiological systems and cause some measure of wear and tear. The model of "allostatic load" was introduced to conceptualize and measure the long-term effects of adaptation to external and internal environmental. The ambiguous term stress is rejected in favor of a more comprehensive term 'allostatic load', which designates the price the body has to pay for its repetitive physiologic efforts (McEwen, 1998c; McEwen & Seeman, 1999). It encompasses many aspects like genes, early development, and learned behavior that all influence the efficient regulation of physiological systems. This holistic concept of allostatic load is the framework of the stress definition of this thesis.

3.2 Stressors at work

In Western economies working life has undergone major structural changes since the beginning of the 1990s. Increased global competition, new technological advancements, more part-time work and flexible time arrangements, to name just a few, have had a considerable impact on work organization and the workplace (Semmer, 2003; Ulich, 2001). As a consequence, many of the fundamental conditions underlying the organization of work have changed (Resch, 2002). With technological advances, workplaces with physical and hazardous working conditions have reduced in number, whereas so-called psychosocial demands that primarily affect the central nervous system have increased (Belkic, Landsbergis, Schnall, & Baker, 2004; Resch, 2002; Siegrist & Marmot, 2004).

According to their theoretical perspective, theories on job stress differ in defining and quantifying the "toxic" elements of the work environment. Traditionally, the discipline of working and organizational psychology has emphasized the role of (objective) working conditions and the working environment in health and well-being (Mohr & Udris, 1997; Ulich, 2001). Accordingly, Karasek (Karasek & Theorell, 1990b) has focused on the amount of job strain arising from the degree of decision latitude and the demands experienced by the individual. From a different, i.e. sociological perspective that includes macroeconomics, Siegrist (Siegrist, 1996; Siegrist, 2002b) has emphasized the importance of reciprocal social exchange, as, for example mediated by the work role and specified in the work contract. According to that perspective, stress is the result of a violation of reciprocity between job-related costs and gains. There are also directions of occupational research that has focused on (subjective) person-specific conditions, such as – to name just a few – negative affectivity (Watson & Clark, 1984; Watson & Pennebaker, 1989), Type A-behavior pattern (Contrada, Glass, Krakoff, Krantz, Kehoe, Isecke et al., 1982; Krantz, Contrada, Durel, Hill, Friedler, & Lazar, 1988), Type D personality (Pedersen & Denollet, 2003) or self-regulatory processes such as optimism and goals (Schwarzer, 1999).

Considering the preceding, the following classification in Table 1 of job-related aspects, often described in the literature (Mohr & Udris, 1997; Resch, 2002), provides a valuable approach to investigating the toxic element of the working environment by drawing the distinction between the following five categories: task related stressors, regulation obstacles, physical environment, social stressors, and organizational burdens (Semmer & Mohr, 2001).

To what extent stress-related illness should be attributed to the individual or to the environment has been a matter of controversy in the medical and social sciences for many years (Mohr & Semmer, 2002). The fact that stress appraisals are highly individual processes and that there are individual differences in perception have to be taken into account (Lazarus, 1999; Lazarus & Folkman, 1984; McEwen, 1998b; Semmer & Mohr, 2001); thus, the aspect of person-specific stressors is accounted for by including this category in the table. Of note, this table contains job-related stressors as well as job-related resources that have been shown to be of importance, such as feeling of coherence, (Antonovsky, 1979, 1987; Udris, 1990), social support (Schwarzer, Knoll, & Rieckmann, 2003), or others described by (Ducki, 2000; Greif, Bamberg, & Semmer, 1991; Udris & Frese, 1999). According to recent stress theories (Levine & Ursin, 1991), there are interactions between situation- and person-specific stressors and resources, enhancing the complexity of the relationship between work and health.

Table 1: Stress-related aspects of work, adapted from (Semmer & Mohr, 2001)

Situation specific stressors
1. Task related aspects — Demands on executive control: complexity, variability, social demands, requirement to cooperate (qualitative demands) — Resources: Control, opportunities for cooperation and communication
2. Obstacles to task performance — Overtaxing task requirements: Time pressure, monotony (quantitative demands) — Work organization: Quality, availability of tools and materials, disruptions — Insecurity: Unclear or conflicting goals, unclear results, unclear feedback
3. Physical environment — External work factors (nose, heat), physical strain, shift work
4. Social aspects — Missing social support, conflicting work relations, unsupportive co-worker and supervisor behavior
5. Organizational aspects — Job position and recognition/esteem, companies policies, control and influence, perspectives, job insecurity
Person specific stressors
6. Individual's beliefs — Hardiness, Self-Efficacy, Optimism, Sense of coherence, Negative affectivity
7. Individual's behaviours — Coping (problem or emotion oriented coping), health-related behaviour (smoking, diet, physical exercise)

Kasl (Kasl, 1992) suggested that occupational stressors can be considered a long-term risk for health and well-being if four conditions are met: (1) The stressful situation is chronic, (2) an adaptation is difficult, because permanent adaptation and concentration is required, (3) there are serious consequences associated with failure to meet demands, and (4) the problems affect other spheres of living, resulting in cumulative effects. In the long run, a vicious circle of increasing vulnerability may ensue that diminishes resources, while the individual needs more resources to meet the external challenges (Schönpflug, 1987). The extent to which specific constellations preferentially influence specific health consequences is not clear yet. However, there is some evidence that work-related demands particularly affect health complaints, whereas the working content and resources primarily affects aspects of evaluation of the self such as self-esteem, self-confidence, and depression (Greif, Bamberg, & Semmer, 1991). The mechanisms of how stress influence the pathogenesis of disease is the topic of the allostatic load concept that will be referred to in chapter 4.4.

3.3 Work stress models

One of the dominant foci of research in the medical and psychological community has been the workplace, linking workplace characteristics to adverse health outcomes. Numerous longitudinal studies support the claim that there is an inverse relationship between unfavorable psychosocial work environments and employee health and well-being (Blane, 1999; Hemingway & Marmot, 1999; Karasek & Theorell, 1990b; Krantz & McCeney, 2002; Levi, Bartley, Marmot et al., 2000; Rozanski, Blumenthal, & Kaplan, 1999; Siegrist, 2002b). In the past decades, specific conditions of chronic work stress and their impact on physical health were examined with the help of different theoretical models (Karasek & Theorell, 1990b; Levi, Bartley, Marmot et al., 2000; Semmer & Mohr, 2001; Siegrist, 2002b). Two prominent models have gained particular attention, allowing the operationalisation of the relationship between job stress and adverse health outcomes: The job strain model, proposed by Karasek and Theorell (Karasek & Theorell, 1990b), in which 'job demands', 'job control' and 'social support' are identified as critical dimensions of the working environment, and the effort-reward imbalance model that was developed by Siegrist (Siegrist, 1996) (Siegrist, 1986), and emphasizes the notion of reciprocity at work.

Although the job strain model is not directly at the focus of this thesis, a more detailed description of the two models is presented here to clarify their respective approaches to understanding the work environment.

3.3.1 The Job-strain Model

Theoretical Background

In 1979, Karasek introduced the demand-control or ‘job-strain’ model (Karasek, 1979). It became one of the most frequently used models for psychosocial working conditions and health in the job stress research (Karasek, 1979; Karasek & Theorell, 1990b). The job strain model as conceptualized by Karasek and Theorell postulates that a combination of high psychological demands with low control at work (‘high strain’) leads to mental and physical illness (Karasek, Baker, Marxer, Ahlbom, & Theorell, 1981; Karasek, Theorell, Schwartz, Schnall, Pieper, & Michela, 1988). The two core dimensions of the model – ‘psychological job demands’ and ‘decision latitude’ or ‘control’ – were later supplemented with a third dimension: Social support at work (Johnson & Hall, 1988; Johnson, Hall, & Theorell, 1989). Using the expanded model, persons with high job strain and low support (so-called ‘iso-strain’) are at the highest risk of adverse health outcomes. For example, assembly line workers, unskilled industrial workers, city bus or tram drivers, and low level clerical workers are faced with high strain workplace conditions.

In the original model, the psychosocial work environment was described as follows: Decision latitude was defined as the workers ability to use skills or the decision-making authority available to the worker (Karasek & Theorell, 1990b). This dimension comprises the individual's possibility to influence his or her own work by exploring new methods and ways of accomplishing the job, possibilities for learning, taking responsibility, being independent, developing and using own skills and knowledge, and experiencing variation at work (Lundberg, 2000). Psychological demands refer to the quantity of work, the mental requirements, and time constraints such as time pressure, work pace, deadlines, etc. Interaction of high and low levels of decision latitude and psychological demands generates a two by two table with four different psychosocial work characteristics: high strain jobs (high demands and low control), active jobs (high demands and high control), low strain jobs (low demands and high control) and passive jobs (low demands and low control).

		Psychological Demands	
		Low	High
Decision latitude	High	Low strain	Active
	Low	Passive	High strain

Figure 2: The job-strain model.

The job-strain model emphasizes the interaction between demands and control in causing adverse health outcomes: High psychological demands do not impair health per se, but they produce adverse health effects when they coincide with a low level of decision latitude (high-strain). Job strain occurs when the individual is psychologically overloaded, and similarly deprived of control over the work environment. According to the model, this is the worst conceivable situation, and it produces passivity, learned helplessness, and lack of participation at work and in the community (Schnall, Landsbergis, & Baker, 1994). A favorable work situation is constituted when high demands are combined with high decision latitude (active job). This favorable condition is a characteristic for many high-status jobs and is associated with active learning and the motivation to develop new behavioral patterns (Schnall, Landsbergis, & Baker, 1994). Employees who have few demands placed on them along with a low level of control become passive both at work and outside of work. This is thus known as a 'passive job'. Finally, a work situation characterized by low demands and high control is defined as a low-strain job. According Karasek and Theorell (Karasek & Theorell, 1990b), low strain and active work environments constitute the most favorable work conditions regarding employee's health.

Lack of social support (social isolation) was later supplemented as a third dimension to the model, and defines the very critical work situation of 'iso-strain', that is, a combination of high demands, low decision latitude, and lack of social support (Johnson & Hall, 1988). Social support has long been a potential moderating variable in the case of high demand and low control (Johnson, 1996; Johnson & Hall, 1988; Karasek & Theorell, 1990b). Work-based social support as a concept includes the support people receive from colleagues and supervisors at the workplace. Social support is usually distinguishes between instrumental and emotional support (Schwarzer, Knoll, & Rieckmann, 2003). Instrumental support is direct assistance in completing a task or reaching a goal, for example, when an employee receives guidance or practical assistance from a supervisor. Socio-emotional support places the emphasis on the interaction and the personal support, for example, when a colleague listens to a person's personal problems. A distinction is usually made between coworker support and support from a superior (Karasek & Theorell, 1990b). Social support outside of work, such as support from family or friends, is usually not included in the model. Social support can mediate the relationship between working conditions and well-being in different ways. Social support can, for example, act as a buffer and thereby alleviate the effect of psychological stressors at work on health. Social support can also lead to individuals employing, what is known as, problem-focused or action oriented coping patterns (Karasek & Theorell, 1990b). With the addition of social support, the model includes eight types of work – the four original types either in combination with or without support.

Empirical Studies

The job strain model has been the most widely used model for evaluating the psychosocial work environment and its potential impact on the cardiovascular system, such as myocardial infarction (MI), coronary artery disease (CAD), and CVD-related mortality (Belkic, Landsbergis, Schnall et al., 2004; Kristensen, 1996; Marmot, Theorell, & Siegrist, 2002) (Landsbergis, Schnall, Belkic, Baker, Schwartz, & Pickering, 2001). The literature on job strain and CVD has been reviewed by several authors (Belkic, Landsbergis, Schnall et al., 2004; Karasek & Theorell, 1990a; Kristensen, 1989, 1996; Schnall, Landsbergis, & Baker, 1994). To date, about 50 studies, 17 of which were conducted as prospective studies using cardiovascular disease as primary endpoints, have been published. The majority of the empirical studies on job strain and CVD supported the main hypothesis that there is an association between low decision latitude and CVD outcomes. Few studies have investigated the interaction between demands and control. In the positive studies, the odds ratios of job strain ranged from 1.2 to 5.0. Several studies found associations between demand or control and the prevalence of cardiovascular risk factors like hypertension, atherogenic lipids, and fibrinogen (Belkic, Schnall, Landsbergis, & Baker, 2000; Belkic, Landsbergis, Schnall et al., 2004; Schnall, Landsbergis, & Baker, 1994). On the other hand, there have been several non-confirmatory findings concerning job strain and CVD outcomes within large-scaled studies, see for example (Hall, Johnson, & Tsou, 1993; Hlatky, Lam, Lee, Clapp-Channing, Williams, Pryor et al., 1995). In a recent published paper, Belkic and colleagues reviewed 17 longitudinal studies, of which nine were case-controlled and eight cross-sectional, following a selection process with a predefined set of criteria (Belkic, Landsbergis, Schnall et al., 2004). Eight of the 17 longitudinal studies reported significant positive results with OR ranging from 1.21 (95% CI 1.08-1.35) (Hammar, Alfredsson, & Johnson, 1998), to 4.0 (95% CI 1.1-14.4) (Karasek, Baker, Marxer et al., 1981) for men and from 1.3 (95% CI 1.1-1.6) (Hammar, Alfredsson, & Johnson, 1998) to 1.74 for women (95% CI 1.15-2.64) (Bosma, Marmot, Hemingway, Nicholson, Brunner, & Stansfeld, 1997). Of the nine case-control studies, Belkic et al reported six with significant results for the relationship of job strain to risk of CVD outcomes, with overall effect sizes ranging from a relative risk of 1.45 (95% CI 1.02-2.00) to an odds ratio of 2.3 (95% CI 1.22-4.4). Additional evidence was provided by four of the eight reviewed cross-sectional studies between job strain and CVD among men with effect sizes ranging from a standardized odds ratio of 1.5 (95% CI 1.07-2.1) for prevalence of MI to a standardized odds ratio of 2.46 for self-reported angina pectoris. Belkiz et al (Belkic, Landsbergis, Schnall et al., 2004) conclude that there is a strong and consistent evidence of an association between exposure to job strain and CVD, especially among men. At least as far as the dimension of low decision latitude is concerned, this conclusion is in line with other reviews on the Job strain model: it is a theoretical model demonstrating a well tested theoretical approach (Landsbergis, Schnall, Belkic et al., 2001; Peter & Siegrist, 2000; Schnall, Landsbergis, & Baker, 1994) with findings that are most consistent in men, blue collar workers, and in populations under the age of 55.

3.3.2 Effort-Reward-Imbalance Model

Theoretical Background

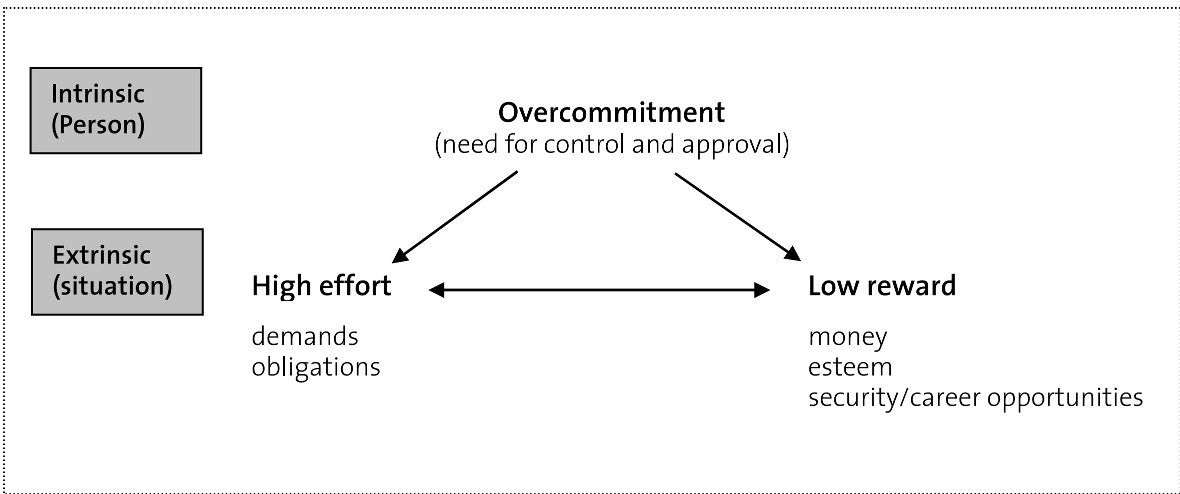
In 1986, a sociological framework, the Effort-Reward-Imbalance (ERI) Model was devised by Siegrist et al. (Siegrist, 1986) in order to predict and explain the incidence of cardiovascular disease. The ERI model has its origins in medical sociology and emphasizes the notion of social reciprocity, a fundamental principle of interpersonal behavior and an 'evolutionarily old' grammar of social exchange (Cosmides & Tooby, 1992; Marmot, Siegrist, Theorell, & Feeney, 1999). Social reciprocity is characterized by mutual cooperative investments that can be understood as a process of exchange in which the norm of return expectancy is reflected in efforts being recompensed with appropriate rewards. Strong negative emotions and sustained stress responses are associated with violations of the principle of reciprocity. In other words, it is assumed that the imbalance between high effort spent and low rewards received is likely to elicit recurrent negative emotions and sustained stress responses in exposed employees. Conversely, positive emotions evoked by appropriate social rewards promote well-being and health. The ERI model hypothesizes that a failed reciprocity may adversely affect the stress regulatory mechanisms, which in turn trigger subsequent secondary biological alterations involved in the pathogenesis of coronary heart disease (Siegrist, 1996; Siegrist, 2002b; Siegrist & Peter, 2000).

The ERI model puts specific emphasize on the social roles (i.e. the work role) and in particular its contractual basis, because according to the model the work role is crucial in order to satisfy individual self-regulatory needs: The workplace offers opportunities to acquire self-efficacy (e.g., successful job performance), self-esteem (e.g., recognition), and self-integration (e.g., belonging to a significant group). According to the model, effort at work is spent as part of a social contract that reciprocates effort by adequate reward (Siegrist, 1986; Siegrist & Peter, 2000). Rewards are distributed by three types of work-related rewards; money, esteem, and status control. Low promotion prospects, forced job change, job instability, and job insecurity are all examples of poor status control.

Based on the principle of reciprocity, the employee invests efforts and expects rewards. According to (Siegrist, 2002b), high effort-low reward-conditions are maintained (1) when work contracts are poorly defined or employees have no alternative choice in the labor market (e.g. due to low level of skill, lack of mobility, precarious labor market), (2) when employees accept this imbalance for strategic reasons (e.g., expecting future gains), and (3) when the employee exhibits a specific cognitive and motivational pattern of coping with demands characterized by excessive work-related commitment ('overcommitment'). Employees characterized by excessive work-related overcommitment misjudge the balance between the demands at work and their own resources for coping. They underestimate the external demands and overestimate the own coping resources, while not being aware of their own contribution to the imbalance between effort and rewards (Siegrist, 2002b). Thus, they are exposed to prolonged non-reciprocal exchange (Siegrist, 1996). Examples of items are 'I have constant time pressure due to a heavy work load' (effort) or 'I have many interruptions and disturbances in my job' (effort); 'My job promotion prospects are poor' (reward), or 'I experience adequate support in difficult situations'.

Overcommitment is seen as a set of attitudes, behaviors, and emotions based on the cognitive and motivational elements of Type A behavior that reflect an exorbitant ambition in combination with the need for approval and esteem (Hanson, Schaufeli, Vrijkotte, Plomp, & Godaert, 2000; Siegrist, 1998). In the recent model, the scale overcommitment comprises items that originally derived from the construct of "need for control". Need for control was described by need for approval, competitiveness, disproportionate irritability, and inability to withdraw from work. Examples of items are 'work rarely lets me go, it is still on my mind when I go to bed' (inability to withdraw from work) or 'I easily get overwhelmed by time pressures at work' (disproportionate irritability). With the concept of overcommitment, the ERI model encompasses not only situation-specific, work-related dimensions (effort, rewards), but also a person-specific component (Siegrist, 2001). A graphic representation of the current ERI model (Siegrist, 1996) is given in the following figure. The items of the recent ERI models are presented in the Appendix.

Figure 3: The effort-reward-imbalance model (Siegrist, 1999), p. 40



The following three hypotheses are derived from the ERI model (Siegrist, 2002b), and should be covered by a complete test of the model (van Vegchel, de Jonge, Bosma et al., 2004).

(1) *The extrinsic ERI hypothesis*: The mismatch between high effort and low reward (non-reciprocity) produces adverse health effects.
(2) *The intrinsic overcommitment hypothesis*: A high level of personal commitment (overcommitment), possibly resulting in continued exaggerated effort combined with a disappointing gratification increases the risk of reduced health (even if ERI is absent).
(3) *The interaction hypothesis*: Relatively highest risks of reduced health are expected in people who are characterized by conditions (1) and (2).

Empirical results

Until today, the effort-reward-imbalance model has been tested in more than 30 prospective and cross-sectional studies. Table 2 shows selected findings from prospective and large cross-sectional studies published up to now.

Table 2: Effort-reward imbalance at work and cardiovascular risk and disease (Tsutsumi & Kawakami, 2004; Siegrist, 2002b) (prospective and large cross-sectional studies studies).

Author (year)	Total Sample (% women)	Measure	Outcome	Adjustment	Multivariate OR (95% CI)
(Siegrist, Peter, Junge, Cremer, & Seidel, 1990)	416 (0) German Blue-collar 25-55 yrs. Follow-up 6.5 yrs.	High effort, low reward (overcommitment)	Incident fatal or non-fatal acute MI	Age, BP, Cholesterol, BMI	4.53 (1.15-17.80)
(Bosma, Peter, Siegrist et al., 1998)	10.308 (33) British civil servants (Whitehall II study) 35-55 yrs. Mean follow- up 5.3 years	High effort, low reward	Newly reported coronary heart disease (angina, doctor diagnosed ischemia)	Age, sex, smoking, BP, cholesterol, BMI, employment grade, NA, length (FU), job control	2.15 (1.15-4.01)
(Kuper, Singh-Manoux, Siegrist et al., 2002)	7830 (33) British civil servants (Whitehall II study) 35-55 yrs. Mean follow-up 11 yrs.	High effort, low reward	Incident fatal or non-fatal acute MI, CAD hazard ratio (HR)	Age, sex, grade	1.28 (0.89-1.84) 1.36 (1.12-1.65) CAD (HR)
(Kivimaki, Leino-Arjas, Luukkonen et al., 2002)	812 Finish employees (30) Mean follow-up 26 yrs.	High effort, low reward	Cardiovascular mortality	Age, sex, grade, biological and behavioral risks at baseline	2.4 (1.33-4.4)
(Peter, Alfredsson, Hammar et al., 1998)	5.720 (44) Swedish population based men and women. 40-55 yrs.	High effort, low reward	Hypertension, total cholesterol, LDL and HDL cholesterol	Age, smoking, BMI, physical exercise, socioeconomic group, hypertension, total cholesterol	ERI (men): 1.62 (1.07-2.43) (hypertension) (1.02-1.56) (cholesterol/HDL) OC (women): 1.39 (1.09-1.77) (LDL)
(Peter, Alfredsson, Knutsson, Siegrist, & Westerholm, 1999)	2.228 (0) Swedish male workers 30-55 yrs.	High effort, low reward (ratio), shift work	Hypertension	Age, smoking, BMI, physical exercise, total cholesterol	Day and late shift combined with ERI: 2.21 (1.10-4.42) / Daytime work combined with ERI 1.35 (0.77-2.36)

Cardiovascular risk and diseases

Most research on the association between ERI at work and health concerned cardiovascular diseases, for review, see (Siegrist & Peter, 2000; van Vegchel, de Jonge, Bosma et al., 2004) (Marmot, Theorell, & Siegrist, 2002; Siegrist, 2002b; Tsutsumi & Kawakami, 2004). A recent review counted 24 studies that focused on CVD outcomes (van Vegchel, de Jonge, Bosma et al., 2004). Examples of large prospective cohort studies on CVD incidence are (Bosma, Peter, Siegrist et al., 1998; Kivimaki, Leino-Arjas, Luukkonen et al., 2002; Kuper, Singh-Manoux, Siegrist et al., 2002). In summary, high effort-low-reward conditions has repeatedly shown to be positively associated with the incidence of coronary events (Bosma, Peter, Siegrist et al., 1998; Niedhammer, Goldberg, Leclerc, David, Bugel, & Landre, 1998b; Peter, Alfredsson, Knutsson et al., 1999; Peter & Siegrist, 2000; Siegrist, Peter, Junge et al., 1990). The odds ratio's for CVD incidence ranged from 1.22 to 8.89, meaning that employees in a high-effort-low-reward-situation had an elevated risk of CVD incidence than employees in the reversed working situation (low effort and high reward). Overcommitment has also been associated with increased risks of CVD in four studies, for review see (van Vegchel, de Jonge, Bosma et al., 2004). The risk of developing CVD or even dying as a consequence of it was 1.18 – 4.53 times higher for highly overcommited employees than for their less committed counterparts.

Until today, there is limited knowledge about the psychobiological mechanisms through which effort-reward-imbalance or overcommitment might increase the risk for adverse health outcomes, although several potential pathways have been proposed (Siegrist, 1996). Various research strategies were realized to find these mechanisms, including ambulatory monitoring in naturalistic settings, experimental studies and analyses of innovative biomedical markers in high risk groups identified in the context of epidemiological studies. In the past years, several biological markers has been examined as potential mediators, such as hypertension and systolic blood pressure (Peter, Alfredsson, Hammar et al., 1998; Peter & Siegrist, 1997; Steptoe, Siegrist, Kirschbaum et al., 2004), artherogenetic lipids (e.g. increased total cholesterol; high concentration of low-density cholesterin)(Peter, Alfredsson, Hammar et al., 1998), an impaired fibrinolysis (e.g. decrease in t-PA activity and increase in PAI-1 activity)(Siegrist, Peter, Cremer et al., 1997; Vrijkotte, van Doornen, & de Geus, 1999), ambulatory blood pressure, heart rate, and heart rate variability (Vrijkotte, van Doornen, & de Geus, 2000), and cortisol (Steptoe, Siegrist, Kirschbaum et al., 2004). In detail, overcommitment has been related to an impaired fibrinolytic system (Vrijkotte, van Doornen, & de Geus, 1999), exaggerated cardiovascular reactivity (Vrijkotte, van Doornen, & de Geus, 2004), blood pressure (Matschinger, Siegrist, Siegrist, & Dittmann, 1986; Siegrist & Matschinger, 1989), higher LDL cholesterol (but only for women (Peter, 1998)), more restenosis (Joksimovic, Siegrist, Meyer-Hammer, Peter, Franke, Klimek et al., 1999), morning cortisol (Steptoe, Siegrist, Kirschbaum et al., 2004). Effort-reward-imbalance was related to elevated blood pressure (Peter, Alfredsson, Hammar et al., 1998; Peter & Siegrist, 1997), artherogenetic lipids (Peter, Alfredsson, Hammar et al., 1998), impaired fibrinolysis (Siegrist, Peter, Cremer et al., 1997), and decreased serum levels of high density lipoprotein (HDL) (Irie, Tsutsumi, Shioji et al., 2004).

The interaction of high ERI and high overcommitment was investigated in one study regarding CVD risk factors and three studies regarding CVD symptoms (van Vegchel, de Jonge, Bosma et al., 2004). However, none of these studies found evidence to support the interaction hypothesis, meaning that the risk of developing CVD outcomes under high ERI conditions is not elevated by concomitantly high overcommitment. One major methodological limitation is that the research on ERI and overcommitment has mainly encompassed male populations, meaning that generalizations for woman must be considered with some caution. For example, a study by Peter (Peter, Alfredsson, Hammar et al., 1998) found increased CVD risk for men under high imbalance conditions, whereas women only had an elevated risk due to high overcommitment.

Psychosomatic health symptoms and subjective health

A large number of studies have investigated associations of ERI with self-reported data on health and well-being, for review see (Tsutsumi & Kawakami, 2004; van Vegchel, de Jonge, Bosma et al., 2004): there is evidence from four longitudinal prospective studies (Kuper, Singh-Manoux, Siegrist et al., 2002; Ostry, Kelly, Demers, Mustard, & Hertzman, 2003; Stansfeld, Bosma, Hemingway et al., 1998; Stansfeld, Fuhrer, Shipley, & Marmot, 1999) and about ten cross-sectional studies (van Vegchel, de Jonge, Bosma et al., 2004). The majority of studies found that effort-reward imbalance was positively related to psychosomatic health symptoms, such as self-reported health (Godin & Kittel, 2004; Niedhammer, Tek, Starke et al., 2004) (Pikhart, Bobak, Siegrist, Pajak, Rywik, Kyshegyi et al., 2001; Stansfeld, Bosma, Hemingway et al., 1998), poor well-being (de Jonge, Bosma, Peter, & Siegrist, 2000), and depression (Pikhart, Bobak, Pajak et al., 2004; Tsutsumi, Kayaba, Theorell et al., 2001). The odds ratio's for elevated risk of impaired well-being ranged from 1.44 to 18.55 for high imbalance (van Vegchel, de Jonge, Bosma et al., 2004). About nine studies have linked overcommitment with impaired well-being, such as musculoskeletal pain (Joksimovic, Starke, v d Knesebeck, & Siegrist, 2002), depression (Tsutsumi, Kayaba, Theorell et al., 2001), psychosomatic complaints (Godin & Kittel, 2004), and self-reported health in men (Niedhammer, Tek, Starke et al., 2004). Most studies consistently reported a positive relationship between high overcommitment and psychosomatic health complaints, resulting in elevated relative risks (RR) ranging from 5.49 to 37.37 (van Vegchel, de Jonge, Bosma et al., 2004). The results with respect to the interaction hypothesis were inconsistent. For example, De Jonge et al (de Jonge, Bosma, Peter et al., 2000) found that the risk for emotional exhaustion due to ERI was higher in overcommited employees, whereas van Vegchel (van Vegchel, de Jonge, Meijer, & Hamers, 2001) found no moderating effect of overcommitment.

A limitation in research relating the ERI model to psychosomatic health symptoms and well-being can be seen in the fact that the majority of studies were cross-sectional (van Vegchel, de Jonge, Bosma et al., 2004). Furthermore, the measurement of effort-reward imbalance and overcommitment was not fixed in the early stages of ERI research, making the comparison difficult (Tsutsumi & Kawakami, 2004). For example, several studies have determined effort-reward-imbalance by combining overcommitment (intrinsic effort in terms of the original model Siegrist 1986) with low reward. Later it was recommended to operationalise ERI as the ratio of effort (numerator) to reward (denominator) (Peter, Alfredsson, Hammar et al., 1998). Again, mainly male populations were investigated, so generalizations for woman are difficult to make. Because there are relatively few studies regarding the interaction hypothesis, the moderating effect of overcommitment is not well understood.

3.3.3 Comparison between Job strain and ERI model

The job strain and the ERI model differ according to their assumptions about the working conditions that are critical for employee's well-being and health. In this section the similarities and differences at the conceptual and measurement level are elaborated. Comparisons concerning their different predictive powers have been reported elsewhere (Bosma, Peter, Siegrist et al., 1998; Calnan, Wadsworth, May, Smith, & Wainwright, 2004; Ostry, Kelly, Demers et al., 2003).

At a conceptual level, the core dimension of the job-strain model is the decision latitude the employee has over his environmental situation at work (in stress-theoretic terms: control). In the ERI model threats to or violations of legitimate rewards based on social reciprocity represent the core dimension (in stress-theoretic terms: reward). While one model employs a control dimension, referring to specific task characteristics, the other model employs a reward dimension, emphasizing the importance of social exchange independently from the actual task characteristics. The effort component of the effort-reward imbalance model resembles the demand component of the job strain model.

According to outcomes, the job strain model covers a broader range than the ERI model because it contains two types of outcome variables: a) health and well-being, and b) active learning and the motivation to develop new behavioral patterns. The ERI model has limited its predictions to health and well-being. An important difference regards the conceptualisation of situational and personal characteristics. The job strain model explicitly focuses on situational characteristics of the psychosocial work environment, whereas employees' personal characteristics are neglected. The ERI model makes an explicit distinction, both at the conceptual and measurement level, between extrinsic (situational) and intrinsic (personal) characteristics (Siegrist, 2002b). In the dynamic version of the job strain model, personal and environmental factors are integrated in a time-dynamic manner. Personal characteristics in the ERI model are conceptualized in terms of style of personal coping, termed overcommitment. However, it should be noted that, in terms of a career perspective, there is a substantial interaction of work exposure experience and coping style, thus lending particular support to the importance of structural conditions. Whereas both models address issues of the proximate psychosocial work environment, more distant labor market conditions are considered as well.

In the ERI model, two of the three dimensions of reward (money, esteem, career opportunities including job security) are closely linked to current labor market developments in the global economy (income stagnation or income loss due to downward mobility or unemployment, blocked career/unavailability of alternative jobs etc.). While the job strain model's major focus, as it has been traditionally measured, is on workplace characteristics, lifetime measures of job control allow for some inference of occupational mobility. It should also be mentioned that `job insecurity´ has been measured in the Job Content Questionnaire on which the job strain model is based.

Both models have the potential to be extended beyond working life and integrated into a lifetime perspective. This is seen as one of the tasks of future research. There is considerable overlap between the measures of demands in the two models. Yet, there is an important difference: whereas DC model concentrates on psychological demands, ERI includes physical demands in its measure and, in some items, is concerned with total workload.

Concerning future research, there is much promise in studying the combined effects of the two models. Preliminary results suggest an additive effect on health outcomes, such a cardiovascular risk. Finally, it is important for policy implications to note that the social relational policy measures derived from both models go substantially beyond the simple, market-based cost/benefit approach that currently dominates the economy.

3.4 Stress reactions

Stress reactions potentially manifest in (a) physiological functions (including alterations in neuroendocrine, autonomic nervous system, immune function), (b) behavior (including aggression or health-related behavior, like smoking and alcohol consumption, (c) subjective experience (including distress and feelings of dissatisfaction, anger, depression, and anxiety, and (d) cognitive functions like alterations in information processing, attention and memory, which may interfere with action performance and decision making (Steptoe, 2000).

Depending on the theoretical point of view, the focus is on different elements of stress responses. For example, research in the tradition of Selye has emphasized the hypothalamic-pituitary-adrenocotical axis and the output of corticosteroids as central elements of stress responses (Steptoe, 2000). Research in the tradition of Lazarus attached importance to the individual appraisal and reappraisal of situations that influence individual coping behavior that in turn has consequences for future health (Lazarus & Folkman, 1984) (Lazarus, 1999). In a more comprehensive conception of stress reactions, the allostatic load framework (McEwen & Seeman, 1999) proposes that the repeated overexposure to neural, endocrine, and immune stress mediators elicited by perseverative stressors can have adverse effects on various organ systems, leading to disease (McEwen & Seeman, 1999). Thus, the allostatic load concept proposes an allostatic cascade; stress elicited production of primary stress mediators over a series of steps cumulating in actual diseases. Table 3 gives an overview over a number of short, medium and long-term stress responses.

Table 3: Possible stress reactions: An overview adapted from (McEwen, 1998b; McEwen & Seeman, 1999; Semmer & Mohr, 2001)

Stress reactions	Short term reactions	Medium to long term reactions	Long term successions
Biological	Norepinephrine, heart rate variability, cortisol	CRP, HbA1C, systolic blood pressure, fibrinogen, D-dimer	Waist-to hip ratio, BMI, hypertension, arterial wall thickening
Physiological	Allostasis Alterations in autonomic nervous system, neuroendocrine system, cardiovascular system, immune function	Allostatic load	Allostatic load CVD (CAD, MI, angina pectoris) Sudden death
Psychic	Strain; anger; frustration Anxiety, worry Feeling of monotony	Psychosomatic complaints Dissatisfaction, resignation, depressed mood Sleep disturbances, disturbed recovering Worry, anticipatory anxiety	Burnout, Exhaustion Depression Decreased health-related quality of life
Behavioral	Individual: decrease in performance, action errors, omission of controlling actions Social: conflicts, quarrels, aggression, withdrawal	Higher consumption of psycho-stimulants (tobacco, alcohol, medicaments) Adverse diet behavior	Absenteeism, passive spare time

3.5 Physiological Stress Reactions

Physiological stress reactions include several biological systems: the sympathetic-adrenal-medullary (SAM) axis, the hypothalamic-pituitary-adrenal (HPA) axis, the haemostatic system, and the immune system. In the following section, selected physiological stress response systems will be briefly described, because their transmitters/hormones are part of the allostatic load measurements used in the present thesis.

Alterations in the autonomic nervous system

The autonomic nervous system (ANS) (also vegetative or visceral nervous system) is the part of the nervous system that controls and regulates the internal organs such as the cardio-respiratory organs, and the gastrointestinal and genitourinary tracts without any conscious control or effort by the organism. The ANS is divided into three parts: The sympathetic, parasympathetic, and enteric nervous system (Schmidt, Lang, & Thews, 2004). The sympathetic nervous system helps control the reaction of the body to stress, while the parasympathetic system works to conserve the body's resources and to restore the equilibrium to the resting state. The enteric system controls the function of the gut. The autonomic system is vital to the maintenance of internal homeostasis and achieves this by mechanisms that regulate blood pressure, fluid and electrolyte balance, and body temperature. The ANS is directly involved in tonic, reflex, and adaptive control of autonomic function, and integrates autonomic with hormonal and immunomodulatory controlling responses to internal and external environmental challenges (Birbaumer & Schmidt, 1999).

The sympathetic and parasympathetic nervous system consists of two populations of pro- and postganglion neurons that are synaptically linked within the vegetative ganglions. The neurotransmitter of the preganglion neurons of the sympathetic nervous systems is acetylcholine (ACh). In sympathetic postganglion neurons the neurotransmitter is nor-epinephrine that binds to α- and β-receptors (Birbaumer & Schmidt, 1999). Epinephrine and nor-epinephrine belong to the group of catecholamines. When released into the blood, they induce increased heart rate, blood pressure, heart contractibility, breathing rate, muscular blood flow, and mental alertness. They also reduce the amount of blood going to the skin and increase blood flow to the major organs (such as the brain, heart, and kidneys). In short, stimulation of the sympathetic nervous system quickly mobilizes the body for emergencies and evokes responses characteristic of the fight-flight response.

The main nerves of the parasympathic system arises from the cell bodies of the motor nuclei of the cranial nerves III, VII, IX and X in the brain stem and from the second, third and fourth sacral segments of the spinal cord (Carlson, 1998). Parasympathetic ganglions are located in the immediate vicinity of the target organs; postganglionic fibers are therefore relatively short. The neurotransmitter at both pre- and postganglionic synapses in the parasympathetic system is Acetylcholine (ACh). In physiological terms, the parasympathetic system is concerned with conservation and restoration of energy, as it causes a slowing down in heart rate and blood pressure, and facilitates digestion and absorption of nutrients (Carlson, 1998; Schmidt, Lang, & Thews, 2004).

Alterations in the endocrine nervous system

The hypothalamic-pituitary-adrenal (HPA) is the primary stress related pathway that links central nervous and endocrine systems in order to prepare the body for changes in the environment. Circulating glucocorticoid concentrations are largely under the control of the HPA axis. Its stimulation by afferent input from the higher central nervous system induces an activation process on three different levels of the hypothalamus, the pituitary gland, and the adrenal cortex (Schmidt, Lang, & Thews, 2004). Corticotropin-releasing hormone (CRH), the principal hypothalamic regulator of the HPA axis, stimulates the secretion of adrenocorticotropic hormone (ACTH) from the anterior pituitary, which in turn stimulates glucocorticoids secretion from the adrenal cortex (Charmandari, Kino, & Chrousos, 2004). Glucocorticoids exert a negative feedback effect on the secretion of CRH of the hypothalamus, on the secretion of ACTH by the anterior pituitary, and on suprahypothalamic centers that control the activity of the HPA axis (Chrousos, 1998; Chrousos, McCarty, Pacak, Cizza, Sternberg, Gold et al., 1995; McEwen, 2000a). The inhibition of CRH and ACTH secretion serves to limit the duration of the total tissue exposure to glucocorticoids, thus minimizing the known catabolic, lipogenic, anti-reproductive, and immunopressive effects of these hormones. Therefore, glucocorticoids play a key regulatory role in maintaining basal and stress-related homeostasis and preserving normal physiology.

Glucocorticoids are involved in every organ system of the human organism and have regulatory effects in nearly all physiologic, cellular, and molecular networks (Charmandari, Kino, & Chrousos, 2004). Almost every tissue in the body has intracellular glucocorticoid receptors (Sapolsky, Romero, & Munck, 2000). Regarding metabolism, glucocorticoids serve the genesis and neogenesis of glucose, while promoting lipolysis and proteolysis. Thus, they increase the available energy in the organism. Regarding the cardiovascular system, they regulate vascular reactivity by acting on both endothelial and vascular smooth muscle cells (Yang & Zhang, 2004). In the central nervous system, glucocorticoids inhibit the transport of glucose into brain cells and promote the catecholamines' effect of enhancing cardiovascular activity and thereby cerebral blood flow. Another effect of glucocorticoids on the CNS relates to the memory function. Here, glucocorticoids act in two opposing ways. While basal levels enhance emotionally charged memory formation, stress levels suppress memory (Seeman, McEwen, Singer, Albert, & Rowe, 1997). In general, the activity of the HPA axis and its regulation of glucocorticoids is essential for normal physiological functioning and maintaining homeostasis. However, prolonged activation of the HPA axis may lead to a number of disorders that arise as a result of increased and prolonged secretion of CRH and/or glucocorticoids, such as hypertension (Bjorntorp, Holm, Rosmond, & Folkow, 2000), abdominal obesity (Bjorntorp & Rosmond, 2000), bone mineral loss (Williams & Nesbitt, 2001), suppression of immune responses (Tsigos & Chrousos, 2002), atrophy of hippocampus and memory impairment (McEwen, 2002), and psychiatric disorders (von Bardeleben & Holsboer, 1988; Wichniak, Brunner, Ising, Pedrosa Gil, Holsboer, & Friess, 2004).

Alterations in the hemostatic system

Formation and dissolution of blood clots are physiological processes and the result of a delicate dynamic balance between procoagulant and anticoagulant mechanisms (Schmidt, Lang, & Thews, 2004). Activation of hemostasis results in a sequential interaction among a series of proenzymes, enzymes, and inhibitors of the coagulation and fibrinolysis cascades. Didactically, two closely intertwined coagulation pathways are distinguished (von Känel, Mills, Fainman, & Dimsdale, 2001): the first, the intrinsic pathway, is triggered upon contact of clotting factor (F) XII with negatively charged surfaces. The second, the extrinsic pathway, is initiated by the interaction of TF exposed on vascular cells and endothelial cells upon injury with activated FVII in plasma. In a progressive cascade, both pathways converge to form an activation complex that converts prothrombin to thrombin. Thrombin, in turn, stimulates the conversion of fibrinogen to fibrin – the main component of a blood clot. The procoagulant properties of the von Willebrand factor (vWF) derive from its capability to mediate platelet adhesion to sites of endothelial lesions and stabilization of FVIII in plasma. Termination of clot formation involves several anticoagulant mechanisms such as binding of antithrombin III to thrombin resulting in inactivation of thrombin in a thrombin/antithrombin III complex (TAT). The fibrinolytic system removes fibrin clots by breaking down cross-linked fibrin chains into soluble fibrin fragments such as D-dimer. Fibrinolysis is essentially triggered by tissue-type plasminogen activator (t-PA) that converts fibrin-bound plasminogen to fibrin cleaving plasmin; t-PA itself is inhibited by type I plasminogen activator inhibitor (PAI-1) – the main physiologic inhibitor of fibrinolysis – in a t-PA/PAI-1 complex. Of note, elevated plasma TAT and D-dimer levels are markers of a hypercoagulable state as they indicate augmented formation of thrombin and fibrin, respectively. In contrast to individual coagulation and fibrinolysis factors, TAT is understood as activation products of the hemostatic cascade where D-dimer indicates that the entire coagulation and fibrinolysis pathways have been activated (Colman, Clowes, George, Hirsh, & Marder, 2001).

Acute stress results in a simultaneous activation of blood coagulation (e.g. fibrinogen, vWF, platelets) and fibrinolysis (t-PA) (Jern, Eriksson, Tengborn, Risberg, Wadenvik, & Jern, 1989; Kario, McEwen, & Pickering, 2003). Notwithstanding this simultaneous activation, acute stress increases levels of TAT and D-dimer indicating a hypercoagulable state (Biondi, Farrace, Mameli, & Marongiu, 1996; von Känel, Mills, Ziegler, & al., 2002). This may have provided an evolutionary benefit to our ancestors by protecting from deadly blood loss when injured in fight or flight. Those who survived then transferred their genes promoting a procoagulant stress response to the next generations.

The situation appears somewhat different in patients suffering from atherosclerotic diseases and related impairment in endothelial anticoagulant function. Here, acute mental stress induces increased activities of coagulation or a decrease in fibrinolytic activation (Palermo, Bertalero, Pizza, Amelotti, & Libretti, 1989; Tomoda, Takata, Kagitani, Kinuno, Yasumoto, Tomita et al., 1999). From a pathogenetic perspective it is interesting to note that contrary to hemodynamic changes (i.e., blood pressure and heart rate), the stress-induced hypercoagulability requires longer recovery time once the stressor has ended. Two studies reported that levels of fibrinogen and D-dimer were elevated as compared to baseline 45 min and 14 min, respectively, after the acute stress situation, while increases in blood pressure and heart rate both had returned to baseline levels (Steptoe, Kunz-Ebrecht, Owen, Feldman, Rumley, Lowe et al., 2003; von Kanel, Dimsdale, Adler, Patterson, Mills, & Grant, 2004). Within minutes, sympathomedullary activation with acute stress releases epinephrine from the adrenal medulla and norepinephrine from sympathetic nerve endings in the blood stream (Dimsdale & Ziegler, 1991).

In sum, stress leads not only to an activation of autonomic nervous system and endocrine pathways but also to physiological changes in hemostasis, leading to increased blood coagulation to prepare the body to environmental challenges.

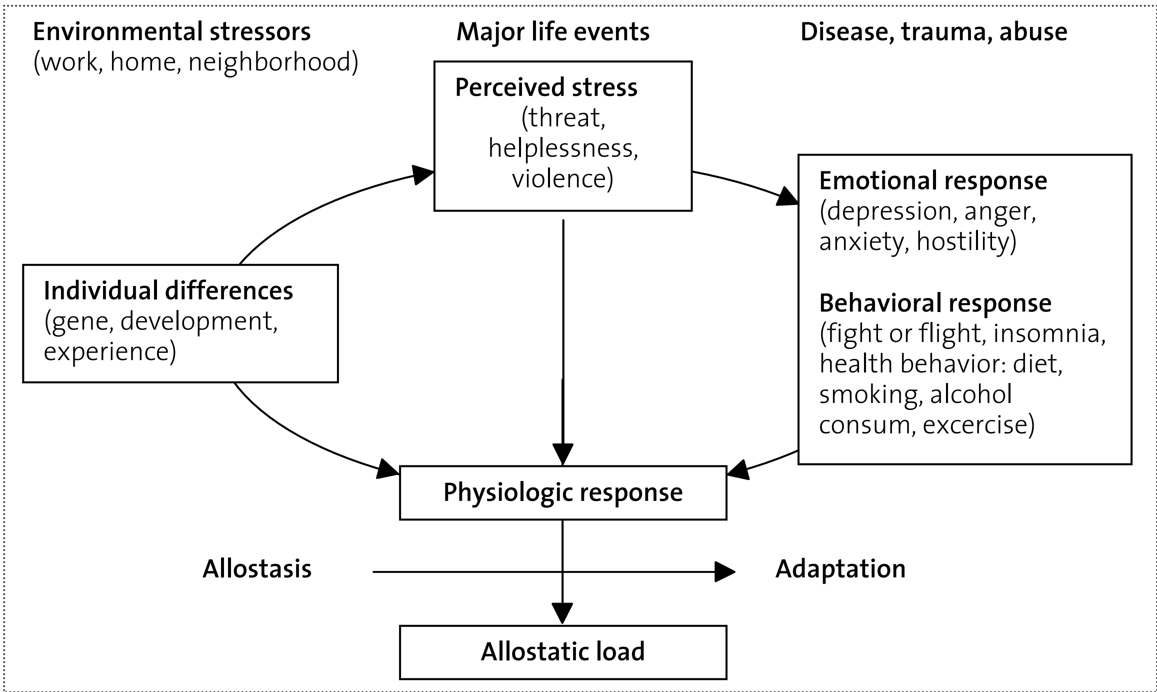
3.5.1 Allostasis

Sterling and Eyer (Sterling & Eyer, 1988) introduced the term "allostasis" (from the Greek allos, also meaning "other") to capture the body's ability to adapt its internal physiologic milieu to external demands. Like Selye, these authors recognized that many physiologic parameters (such as blood pressure and heart rate variability) do not remain constant but vary appreciably in response to experienced stressors. In contrast to homeostatic systems (such as blood oxygen, pH, or body temperature), allostatic adaptive systems have much broader boundaries of operation (McEwen, 2000b) and enable the body to cope with various stressful situations, such as danger, hunger, extreme temperature, infections, psychosocial stress (Kario, McEwen, & Pickering, 2003).

Allostatic stress responses include primarily the activation of the autonomic nervous system and the hypothalamo-pituitary-adrenal (HPA) axis. Physiological mediators of these systems, namely the catecholamines of the sympathetic nervous system and the glucocorticoids from the adrenal cortex, provoke secondary changes in physiological parameters such as blood pressure and plasma lipid concentrations of serum glucose levels (McEwen, 2000b). The main objective of these changes in cells and tissues throughout the body is to adapt the organism optimally to changes in environmental conditions. Normally, the allostatic load triggered by a stressor is to shut off as soon as the stress has passed, and plasma levels of catecholamines and glucocorticoids return to baseline level (Kario, McEwen, & Pickering, 2003). Under physiologic conditions, the stress response has two important features: (1) the first involves "turning on" of physiological systems to an extent adequate to the challenge. (2) The second comprises "turning off" the systems when adaptation is no longer needed (McEwen, 2000b). However, when cycles of allostasis become excessive, allostatic adaptation to stressors will lead to dysregulation in multiple physiological systems (Karlamangla, Singer, McEwen, Rowe, & Seeman, 2002; McEwen, 1998c), causing a wear and tear of the body and exacerbating disease processes. This phenomenon will be described in the next chapter.

Figure 4 illustrates the concept of allostasis and allostatic load. Allostatic responses that protect the body by adaptation are influenced by individual differences in genetic constitution, development, differences in processes of stimulus perception and appraisal, and by behavioral and emotional responses. Emotional responses include depression, anxiety, anger, and hostility; behavioral responses encompass fight or flight, insomnia, and health behavior, which in turn has consequences on physiologic responses in the short and the long run, depending on if its health-promoting activities (i.e. good diet, regular exercise) or behavior exacerbating the physiological consequences of stress (i.e., smoking, drinking, diet).

Figure 4: Stress concept by McEwen and Seeman, adapted from (Kario, McEwen, & Pickering, 2003)



3.5.2 Allostatic Load

Through allostatic processes the autonomic nervous system, the hypothalamic-pituitary-adrenal (HPA) axis, the cardiovascular, and immune systems protect and restore the body by responding to internal and external stressors. Under normal conditions, the allostatic response is initiated by a stressor, sustained for an appropriate period of time, and is then turned off (McEwen, 1998c, 1998b). Under adverse conditions, for example long lasting exposure to stress, the price of permanent accommodation can be ´allostatic load', which is the wear and tear that results from chronic overactivity or underactivity of allostatic systems. Thus, allostatic load designates the inefficient management of the allostatic systems, which have protective effects in the short run, but can have damaging effects over longer periods of time if there are multiple or prolonged demands from the environment (McEwen, 1998c, 1998b).

Four conditions that may lead to allostatic load are distinguished: (1) repeated exposure to stress, (2) lack of adaptation, (3) prolonged physiologic response, and (4) inadequate response. Figure 5 shows these conditions.

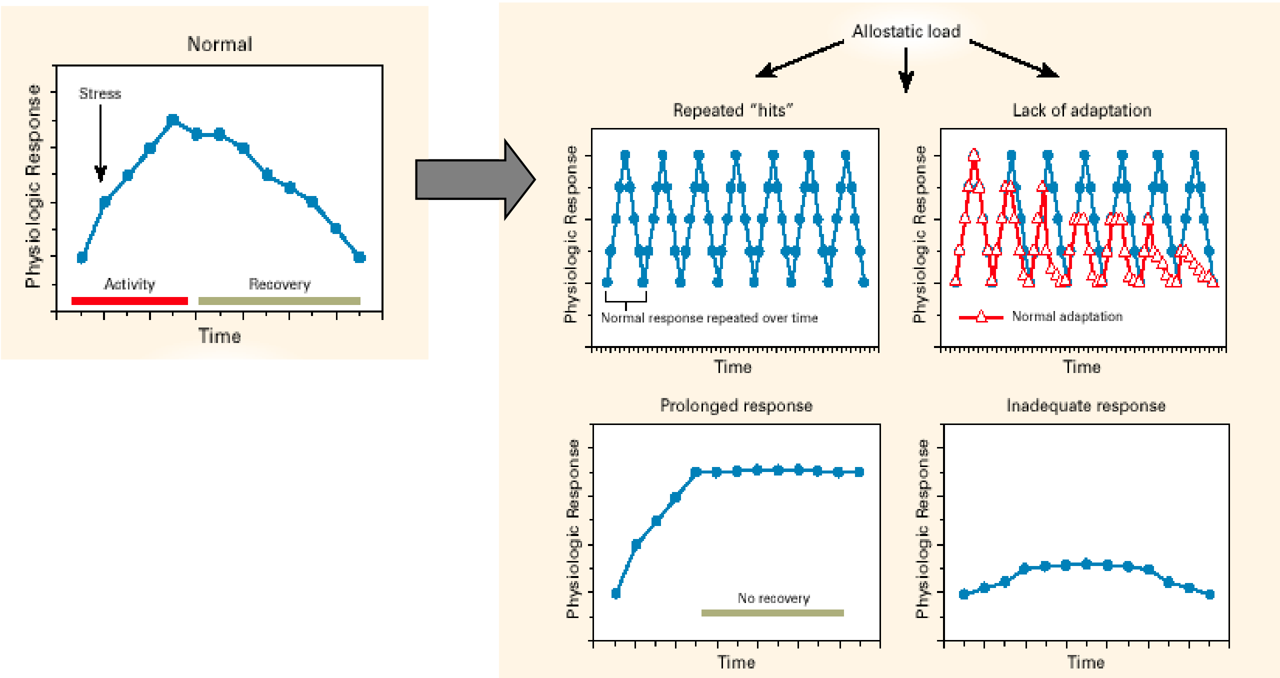


Figure 5: Different conditions of Allostatic Load, figure published by McEwen (1998c), 174.

The first condition is characterized by "repeated hits" in form of recurrent stressful events that cause repeated elevations of stress mediators over long periods of time (McEwen & Seeman, 1999). For example, von Känel et al. (von Kanel, Dimsdale, Patterson, & Grant, 2003b) reported for example significant increases in haemostatic risk factors (i.e., D-dimer) in chronically distressed spousal Alzheimer caregivers as compared to controls. The second condition that may enhance the risk for allostatic load is characterized by a lack of adaptation of the physiological systems in response to repeated exposure to the same stimulus, resulting to an overexposure to the stress mediators although the stressful situation has ended. This type of allostatic load can be illustrated with the paradigm of public speaking tasks like the often applied TSST (Trier Social Stress Test) (Dickerson & Kemeny, 2004; Kirschbaum, Pirke, & Hellhammer, 1993). For example, Kudielka et al. (Kudielka, von Känel, Preckel, L., Mischler, & Fischer, submitted) have recently found that individuals with high degrees of vital exhaustion – a psychological state characterized by unusual fatigue, loss of energy, sleep disturbance and irritability – failed to habituate, namely they showed lower decline of cortisol secretion in repeated public speaking as compared to non-exhausted subjects. The third allostatic load condition regards the inability to turn off the hormonal stress response. For example, acute stress induced alterations in heart rate variability during sleep may represent one mediator of the relationship between stress and disturbed sleep (Hall, Vasko, Buysse, Ombao, Chen, Cashmere et al., 2004). Finally, the fourth condition resulting in allostatic load includes an inadequate response of one allostasis system, leading to compensatory hyperactivity of other mediators (e.g., inadequate secretion of glucocorticoids, resulting in an increased level of cytokines that are normally regulated down by glucocorticoids).

According to McEwen and Seeman (McEwen & Seeman, 1999), the physiological mechanisms connecting allostasis and allostatic load encompasses a series of four stages: The allostatic cascade is initiated by a release of primary stress mediators. These comprise catecholamine and hormones linked to the stress response, i.e. cortisol, norepinephrine, epinephrine, and DHEA (McEwen & Seeman, 1999), p39. Dysregulations of the primary mediators lead to primary effects and, in the long run, to secondary outcomes (McEwen & Seeman, 1999). For example, catecholamine and other stress hormones surge following acute stress (primary mediators), concomitantly activate blood coagulation and fibrinolysis pathways (secondary outcomes) via effects on endothelial 2- and platelet 2-adrenergic receptors (primary effects) (von Känel, Mills, Fainman et al., 2001). A result of allostatic load deriving from extreme values of primary mediators and secondary outcomes are the tertiary outcomes that represent actual diseases or disorders (McEwen & Seeman, 1999). For example, under normal conditions the hemostatic balance between thrombosis and hemorrhage is maintained, reflecting a successful adaptation through change (allostasis). In the presence of atheriosclerosis and impaired endothelian anticoagulant function, however, acute stress may heighten the risk for an atherothrombotic event (tertiary outcome) by eliciting a hypercoagulable state (allostatic load).

In sum, the model states that the biological basis of wear and tear of the organism related to the allostatic cascade involves several progressive steps from primary mediators via secondary outcomes to actual disease. In the next chapter this idea is exemplified more in detail.

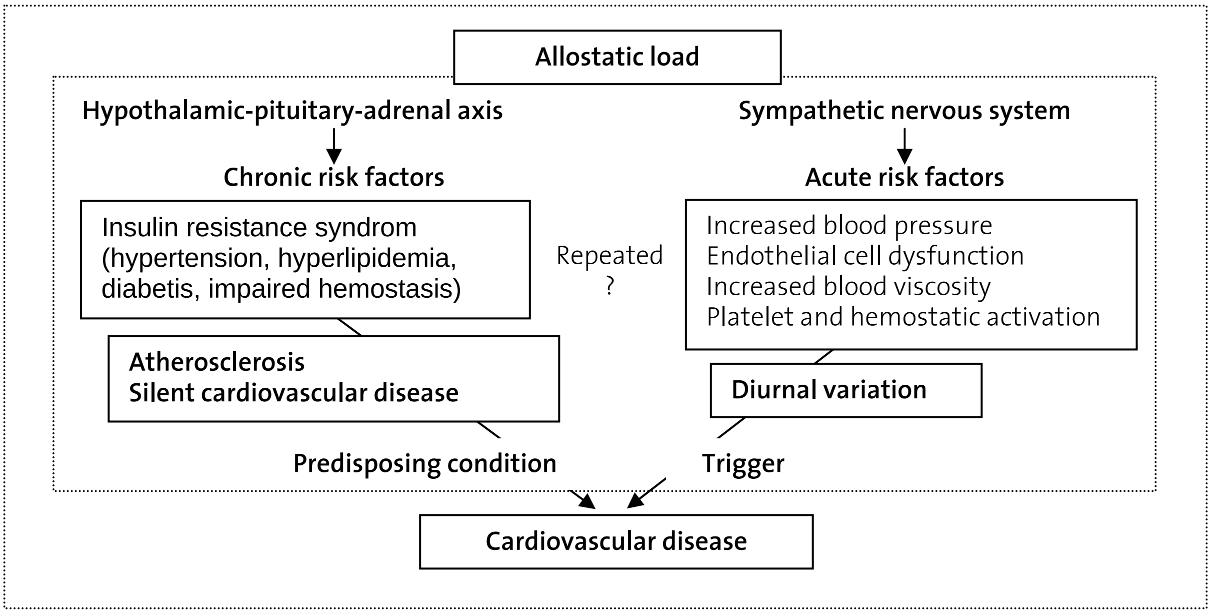
3.5.3 From allostasis to disease: Considering an example

Multiple pathways have been identified that contribute to the progression of arteriosclerosis, i.e. inflammation, lipid deposition, endothelial dysfunction and changes in the hemostatic system (McEwen, 1998c). For brevity, findings pertaining to the allostatic effects of psychosocial stressors on the hemostatic system are discussed.

Chronic stress associated is accompanied by profound changes in cardiovascular risk factors such as hypertension, arteriosclerosis, neuroendrocine and hemostatic changes (Belkic, Landsbergis, Schnall et al., 2004; Everson, Lynch, Chesney, Kaplan, Goldberg, Shade et al., 1997; Landsbergis, Schnall, Belkic et al., 2001; Schnall, Schwartz, Landsbergis, Warren, & Pickering, 1992). The hemostatic system in more detail: Chronic stress leads to a reduced fibrinolytic capacity as evidenced by dwindling t-PA activity and an increase of PAI-1 (von Känel, Mills, Fainman et al., 2001). An increase in plasma fibrinogen levels (von Känel, Mills, Fainman et al., 2001) and in D-dimer (von Kanel & Dimsdale, 2003a) but also in FVII (von Känel, Mills, Fainman et al., 2001) has been found, resulting in net hypercoagulability. Low socioeconomic status and the struggle to cope with the social burden of a low income or poor education are inversely related to plasma fibrinogen and FVII levels (von Känel, Mills, Fainman et al., 2001). Similarly in a number of studies, fibrinogen is higher in subjects who perceived job stress than in those who did not (von Känel, Mills, Fainman et al., 2001). Overcommitment to work, as defined in the ERI model, has been associated with impaired fibrinolysis (i.e., decrease in t-PA activity and increase in PAI-1 activity) (Vrijkotte, van Doornen, & de Geus, 1999). Vital exhaustion – a state characterized by feelings of fatigue, lack of energy, irritability, demoralization, and hostility has been shown to predict cardiovascular disease events (Appels & Mulder, 1988) (Cole, Kawachi, Sesso et al., 1999; Kop, Appels, Mendes de Leon et al., 1994). Several studies have found that subjects who are exhausted have an impaired fibrinolytic capacity as evidenced by an increase in PAI-1 (Kop, Hamulyak, Pernot, & Appels, 1998; Raikkonen, Lassila, Keltikangas-Jarvinen, & Hautanen, 1996; van Diest, Hamulyak, Kop, van Zandvoort, & Appels, 2002; von Kanel, Maly, Frey, & Fischer, 2003). Significant increases in D-dimer have been found in chronically distressed spousal Alzheimer caregivers as compared to age- and gender matched non-caregiving controls (von Kanel, Dimsdale, Adler, Patterson, Mills, & Grant, in press). An association between the number of negative life events within the previous four weeks and plasma D-dimer has been found in a sample of chronic distressed Alzheimer caregivers (von Kanel, Dimsdale, Patterson, & Grant, 2003a). Caregivers who reported relatively more chronic life stress above and beyond that experienced by providing care to their demented spouse had also a higher acute stress procoagulant activity (von Kanel, Dimsdale, Patterson et al., 2003b). Taken together, the hemostatic system could be one of the potential mediators explaining the relationship between job stress and coronary heart disease (Kittel, Leynen, Stam, Dramaix, de Smet, Mak et al., 2002).

Figure 6 illustrates possible mechanisms mediating the pathway from allostasis to disease. As is the case in chronic work stress, repeated adaptation to stressors at the workplace results in accumulating biological burden (allostatic load). Mainly, two systems are involved: The HPA axis and the sympathetic nervous system. Acute risk factors such as increased blood pressure, endothelial cell dysfunction, platelet and hemostatic activation might trigger the progression of atherosclerosis and silent cardiovascular disease that may later manifest in cardiovascular disease. For example, sustained overactivity of the SNS, as tracked by overnight urine catecholamine excretion, is associated with a procoagulant profile in the morning in male factory workers (von Kanel, Kudielka, Abd-el-Razik, Gander, Frey, & Fischer, in press). Overnight sympathetic activity and accompanying catecholamine spillover due to repeated hypoxic bursts and arousals during sleep have been implicated in procoagulant changes observed in patients suffering from obstructive sleep apnea (von Kanel & Dimsdale, 2003b).

Figure 6: Stress concept by McEwen and Seeman, adapted from (Kario, McEwen, & Pickering, 2003)



3.5.4 Measurement of Allostatic Load

The concept of allostatic load was first empirically tested within the MacArthur studies of successful aging (Seeman, McEwen, Rowe, & Singer, 2001; Seeman, McEwen, Singer et al., 1997; Seeman, Singer, Rowe, Horwitz, & McEwen, 1997). Seeman et al. focused on indicators of diurnal HPA and sympathetic nervous system functioning, as well as parameters related to the cardiovascular system and to metabolic processes (Seeman, Singer, Rowe et al., 1997). The following variables were included, representing higher, chronic, steady-state levels of activity or failure to shut off responses to acute stressors.

- Systolic and diastolic blood pressure, indices of cardiovascular activity (Cesana, Sega, Ferrario, Chiodini, Corrao, & Mancia, 2003; Pocock, McCormack, Gueyffier, Boutitie, Fagard, & Boissel, 2001; Strandberg, Salomaa, Vanhanen, & Pitkala, 2001).
- Waist-to-hip-ratio, an index of central obesity and adipose tissue deposition, reflecting adverse nutritional intake (Hecker, Kris-Etherton, Zhao, Coval, & St Jeor, 1999; Lakka, Lakka, Salonen, Kaplan, & Salonen, 2001; Skurk & Hauner, 2004).
- Serum HDL and total cholesterol, related to the development of atherosclerosis (Packard, Nunn, & Hobbs, 2002; Pocock, McCormack, Gueyffier et al., 2001; Spieker, Ruschitzka, Luscher, & Noll, 2004).
- Blood plasma levels of glycosylated hemoglobin (HbA1c), an integrated measure of hyperglycemia over several weeks (Jackson, 2000).
- Dehydroepiandrosteron sulfate (DHEA-S), a functional HPA axis antagonist (Nasrallah & Arafah, 2003).
- Overnight urinary cortisol excretion, an integrated measure of 12-hour HPA axis

activity (Seeman, Singer, Rowe et al., 1997).

— Overnight urinary epinephrine and norepinephrine excretion levels, integrated indices of 12-hour SNS activity (Seeman, Singer, Rowe et al., 1997).

For each of the above 10 indicators, subjects were classified into quartiles. Allostatic load then was generated by summing up the number of parameters for which the subject fell into the highest risk quartile. This was the lowest quartile for HDL and DHEA-S, and the top quartile for all other parameters. This measure of allostatic load was then examined for its ability to predict health outcomes over a 2.5-year follow-up. Higher allostatic load scores were found to predict significantly increased risks for incident cardiovascular disease as well as increased risks for decline in physical and cognitive functioning and for mortality (Seeman, Singer, Rowe et al., 1997). With the data from this longitudinal cohort study, first empirical evidence for the validity of the concept of allostatic load was gathered on a prospective basis.

The MacArthur Study investigators (Seeman, McEwen, Rowe et al., 2001) suggested augmenting the original panel by including indicators of immune functioning, inflammation and hemostasis. Therefore, in study I the measurement of Allostatic load was extended by the following parameters:

— Plasma levels of high-sensitivity C-reactive protein (CRP) as a risk factor of inflammation (Blake, Rifai, Buring, & Ridker, 2003; Folsom, Pankow, Tracy, Arnett, Peacock, Hong et al., 2001; Koenig, 2003).
— Micro-albuminuria as an indicator of subclinical renal impairment (Mimran & Ribstein, 1996) and a risk factor for mortality and CVD (Kannel, Stampfer, Castelli, & Verter, 1984).
— body-mass-index to reflect adverse nutritional intake (Hecker, Kris-Etherton, Zhao et al., 1999; Lakka, Lakka, Salonen et al., 2001; Skurk & Hauner, 2004).
— Plasma levels of D-dimer and fibrinogen as system indicators for hemostasis (von Kanel & Dimsdale, 2003a).

As noted earlier, the concept of allostatic load was designed to summarize encompass physiologic activity across a range of regulatory systems associated with disease risk. The allostatic load parameters indicate functions of regulatory systems, which contribute significantly to wear and tear of the body (Seeman, Singer, Rowe et al., 1997).

3.6 Psychological stress reactions

In occupational research, several potential aspects of occupational stress have been investigated in relation to health outcomes. Numerous studies have investigated psychological concepts such as depression, anxiety, irritability, low self-esteem, and more psychosomatic complaints like heart palpitation, muscle tension, and sleep disorders, for overview (Greif, Bamberg, & Semmer, 1991; Mohr & Udris, 1997). The studies range from findings indicating that impaired well-being is more likely to be reported in low qualified jobs across correlations between working stress and stress symptoms (Greif, Bamberg, & Semmer, 1991) as well as between job uncertainty and psychosomatic complaints (de Jonge, Bosma, Peter et al., 2000). The results of these (and many more other) studies allow the conclusion that connections between occupational stress and psychological conditions exist. For importance, a number of longitudinal studies point into the same direction (Adler & Matthews, 1994; Kahn & Byosiere, 1992) (Niedhammer, Goldberg, Leclerc, Bugel, & David, 1998a; Stansfeld, Bosma, Hemingway et al., 1998; Stansfeld, Fuhrer, Shipley et al., 1999). Given that working stress is only one of many influential factors on health and well-being it is understandable that the effects of the well documented negative consequences of occupational stress are not very large, and that stress does not automatically lead to illness. The correlations usually found are in the range of $r = .20 - .30$. It is conceivable that these small effects have an additive influence on the development of psychological stress symptoms (Greif, Bamberg, & Semmer, 1991; Mohr & Udris, 1997).

3.6.1 Vital Exhaustion

Extensive literature provides evidence that psychological factors contribute significantly to the pathogenesis of cardiovascular disease, for review, see (Krantz & McCeney, 2002; Rozanski, Blumenthal, & Kaplan, 1999). Vital exhaustion has been identified as an independent risk factor for adverse health outcomes, including cardiovascular disease (Appels, Kop, Bar, de Swart, & Mendes de Leon, 1995; Appels, Kop, & Schouten, 2000; Kop, Appels, Mendes de Leon, & Bar, 1996; Kop, Appels, Mendes de Leon et al., 1994; Kop, Hamulyak, Pernot et al., 1998). Excess fatigue and feelings of general malaise have been found by many researchers to be prevalent precursors of myocardial infarction and sudden cardiac death (Appels, 1997b; Kop, Appels, Mendes de Leon et al., 1994). The idea behind the construct of vital exhaustion stemmed from an interest to understand the nature of the feelings of unusual tiredness that, according to cardiological literature, were commonly reported among patients of a recent MI or cardiac death (Appels, de Vos, van Diest, Hoppner, Mulder, & de Groen, 1987). The mental precursors of myocardial infarction (MI) were described as vital exhaustion, a state characterized by unusual fatigue, irritability, and feelings of demoralization, typically attributed to prolonged psychological stress (Appels, 1997a, 1999; Appels, Kop, Bar et al., 1995; Appels & Mulder, 1988; Kop, Appels, Mendes de Leon et al., 1994). In creating the construct of vital exhaustion Appels followed the reasoning of Selye's General Adaptation model postulating that a prolonged period of perceived uncontrollable stress results in a state of vital exhaustion. Therefore, it has been suggested that vital exhaustion is a mental state at which people arrive when their resources for adapting to stress are broken down (Kop, Appels, Mendes de Leon et al., 1994).

Epidemiological studies have shown that vital exhaustion is an independent risk factor for coronary artery disease in both men (Appels & Mulder, 1988) and women (Appels, Falger, & Schouten, 1993). For example, a prospective study among 3877 middle-aged males showed age-adjusted risk of angina pectoris (OR (age-adjusted) = 1.86, $p < .03$) and that of non-fatal myocardial infarction (OR (age-adjusted) = 2.28, $p < .001$), was significantly increased in individuals with higher values of vital exhaustion (Appels & Mulder, 1989). Vital exhaustion has been shown to also predict new cardiac events after successful coronary angioplasty (Kop, Appels, Mendes de Leon et al., 1994; Mendes de Leon, Kop, de Swart, Bar, & Appels, 1996). In occupational research, there are studies demonstrating a relationship between working conditions and vital exhaustion. For example, working overtime has been found to predict both vital exhaustion and myocardial infarction (Falger & Schouten, 1992). In employees of the manufacturing industry, high levels of exhaustion (score >10) were related to excessive workload (scoring in the highest quartile; adj. OR 7.5), to adverse physical work conditions (adj. OR 6.9), to adverse co-worker behavior (adj. OR 4.8), to qualification potential (adj. OR 0.32), and to social support by co-workers (adj. OR 0.34) (Schnorpfeil, Noll, Wirtz, Schulze, Ehlert, Frey et al., 2002).

3.6.2 Health-related quality of life

During the 1990s, the construct of health-related quality of life (HrQoL) was acknowledged as a relevant outcome measure in patient populations (Pais-Ribeiro, 2004). Accordingly, instruments have been developed to provide a standardized method to measure health status and levels of impairment. One of the major reasons for measuring HrQoL was to detect how much HrQoL changes in response to treatments. To date, there are numerous studies that have applied HrQoL measurements in several clinical and healthy populations (Bullinger, 2002).

In recent years, there have been a growing number of publications on health-related quality of life in occupational settings (Amick, Kawachi, Coakley, Lerner, Levine, & Colditz, 1998; Cheng, Kawachi, Coakley, Schwartz, & Colditz, 2000; Stansfeld, Bosma, Hemingway et al., 1998). In a cross-sectional survey, Amick (Amick, Kawachi, Coakley et al., 1998) examined the relationships of job strain and iso-strain (high strain and low work-related social support) to subjective health status in 33,689 women. When compared with active work, high-strain work was associated with lower vitality, mental health, higher pain, and increased risks of both physical and emotional role limitations. Iso-strain work increased the risks further. Job insecurity also predicted lower health status. In a longitudinal study with 21,290 female employees, Cheng et al (Cheng, Kawachi, Coakley et al., 2000) investigated prospective relationships between psychosocial work characteristics and changes in health related quality of life over four years. The results showed low decision latitude, high job demands, and low work-related social support were associated with poor health status at baseline as well as greater functional decline over a four year follow-up period. In jobs characterized by iso-strain the greatest functional decline was observed. These associations could not be explained by possible confounders such as demographics and SES, BMI, co-morbid disease status, health behavior, or presence of a confidant. These findings suggested that high job demands, low job control, and lack of social support at work exert a significant impact on self-reported HRQoL. Stansfeld et al investigated work characteristics and social support as predictors of HrQoL in terms of physical, psychological, and social functioning. Within the prospective Whitehall cohort study of 10,308 British male and female civil servants they applied the SF-36 General Health Survey (Ware, Snow, Kosinski, & Gandek, 1993). After adjusting for potential confounding effects of age, employment grade, baseline ill health, and negative affectivity, they found that effort-reward imbalance and negative aspects of close relationships predicted poor physical, psychological, and social functioning. Psychological demands at work in women, and low confiding/emotional support in men, predicted poor functioning as well. Thus, effort-reward-imbalance appears also to be a crucial aspect in working environment for maintaining a high mental health-related quality of life in white collar workers.

Although the need for an inclusion of HRQoL instruments in the assessment of healthy populations is increasingly acknowledged, there is still a paucity of data regarding predictors of HRQoL. Therefore, further investigations regarding the relationship between effort-reward-imbalance, overcommitment and health-related quality of life, included in this study, are necessary.

3.6.3 Depression

Numerous epidemiological studies have demonstrated a significant prospective relationship between the occurrence of depression and the number of cardiac events (Hemingway & Marmot, 1999; Krantz & McCeney, 2002). Even minor depressive symptomatology is associated with an increased risk of cardiac events, suggesting a gradient relation between depression scores and risk of cardiovascular disease (Rozanski, Blumenthal, & Kaplan, 1999). Individuals with depressive symptoms are more likely to develop coronary disease over time. In a systematic review (Hemingway & Marmot, 1999), all prospective etiological studies that were included on account of their high methodological quality supplied consistent and convincing data for the proposed association (Anda, Williamson, Jones, Macera, Eaker, Glassman et al., 1993; Appels & Mulder, 1988; Aromaa, Raitasalo, Reunanen, Impivaara, Heliovaara, Knekt et al., 1994; Barefoot, Helms, Mark, Blumenthal, Califf, Haney et al., 1996; Barefoot & Schroll, 1996))(Everson, Goldberg, Kaplan, Cohen, Pukkala, Tuomilehto et al., 1996) (Kubzansky, Kawachi, Spiro, Weiss, Vokonas, & Sparrow, 1997; Wassertheil-Smoller, Applegate, Berge, Chang, Davis, Grimm et al., 1996). This result is also supported by a number of prognostic studies (Ahern, Gorkin, Anderson, Tierney, Hallstrom, Ewart et al., 1990; Barefoot, Helms, Mark et al., 1996; Denollet, Sys, Stroobant, Rombouts, Gillebert, & Brutsaert, 1996; Frasure-Smith, Lesperance, & Talajic, 1995; Kop, Appels, Mendes de Leon et al., 1994; Ladwig, Roll, Breithardt, Budde, & Borggrefe, 1994).

In occupational stress research, the impact of working conditions on depression or depressed mood has been examined by several authors. In cross-sectional studies symptoms of depression have been associated with effort-reward imbalance and overcommitment (Tsutsumi, Kayaba, Theorell et al., 2001; Watanabe, Irie, & Kobayashi, 2004) (Godin & Kittel, 2004; Pikhart, Bobak, Pajak et al., 2004). Depression has been linked also to job strain (Karasek & Theorell, 1990b), shift work (Kaneko, Maeda, Sasaki, Sato, Tanaka, Kobayashi et al., 2004), and low social support (Park, Wilson, & Lee, 2004). Some findings suggest a moderating effect of social support on the relationship between adverse working conditions and depression (Watanabe, Irie, & Kobayashi, 2004). Within the participants of the longitudinal Whitehall II study, similar results were yielded (Stansfeld, Fuhrer, Shipley et al., 1999). In addition, there is evidence that job insecurity, a macro-economic stressor becoming increasingly prevalent in contemporary economies, shows synergistic associations with depressed mood (Strazdins, D'Souza, L, Broom, & Rodgers, 2004).

In sum, robust evidence links depression to increased risk of morbidity and mortality in coronary artery disease (Hemingway & Marmot, 1999; Rozanski, Blumenthal, & Kaplan, 1999). Nowadays, depression is widely accepted as a psychosocial risk factor for the etiology and prognosis of coronary heart disease (Krantz & McCeney, 2002). Several cross-sectional and longitudinal studies have demonstrated a relationship between depression and several adverse psychosocial working conditions, such as job strain, effort-reward-imbalance, shift work, low social support, and instable career conditions.

3.6.4 Sleep

Sleep problems (sleep disturbances, insomnia, and poor sleep quality) are frequent complaints in the general population. Epidemiologists have published more than 50 studies of insomnia based on data collected in various representative community-dwelling samples or populations (Ohayon, 2002). It is estimated that between 10 and 35% of the population have insomnia symptoms of various degrees of severity (Ohayon, 2002). In more detail, the estimations of the prevalence of insomnia vary according the definitions (Ohayon, 2002): About one-third of the general population presents at least one of the insomnia symptoms as defined by the DSM-IV. When day-time consequences of insomnia are taken into account, the prevalence is between 9% and 15%. About 8-18% of the general population complains about sleep dissatisfaction. According to the DSM-IV classification for insomnia diagnoses, the prevalence is estimated at 6% of the population. In Germany, the prevalence of insomnia amounts to 28.5% of the population, with 13.5% of the adults reporting moderate to severe insomnia (Weyerer & Dilling, 1991).

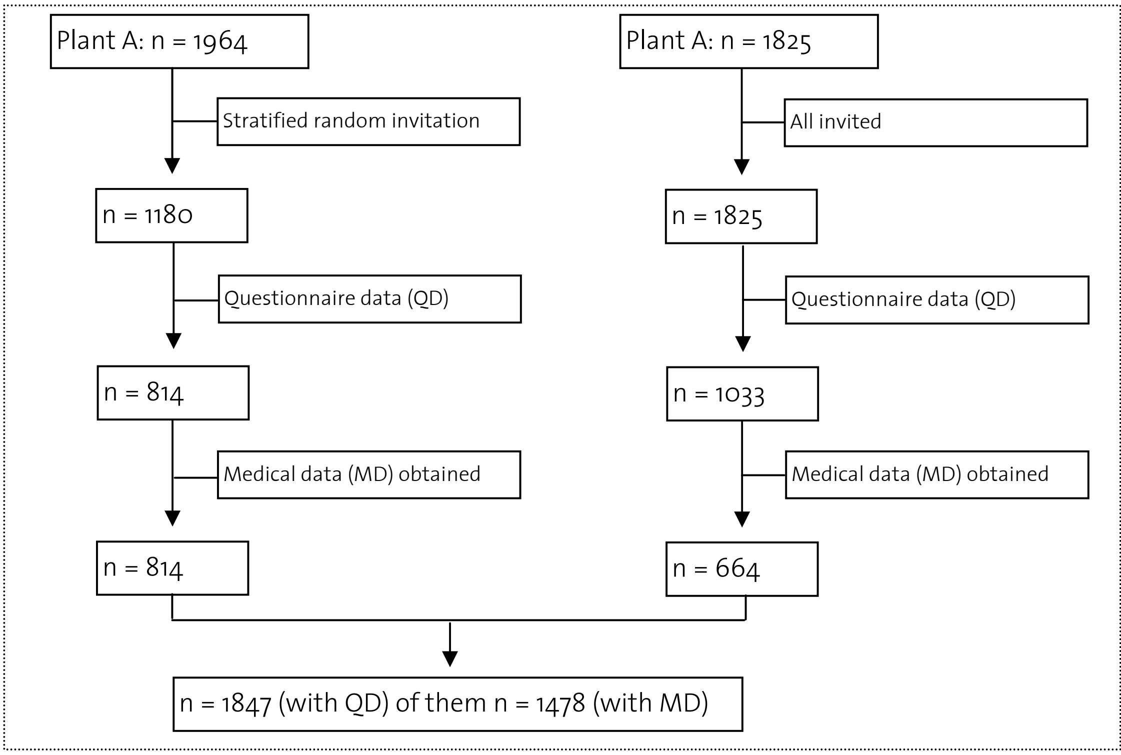
The prevalence of insomnia generally increases with age (Habte-Gabr, Wallace, Colsher, Hulbert, White, & Smith, 1991; Lemoine, Nicolas, & Faivre, 2001; Ohayon, 2002). Women have higher prevalence rates of insomnia than men (Collop, Adkins, & Phillips, 2004; Krystal, 2004; Miller, 2004; Shaver, 2002). Numerous factors can initiate or maintain insomnia or other sleep problems, such as mental disorders like depression (Riemann, Berger, & Voderholzer, 2001) and organic diseases such as fibromyalgia (Fietta, 2004; Thompson, Lettich, & Takeshita, 2003). Low socioeconomic status (SES) is frequently associated with compromised sleep quality, and sleep disorders are discussed as a possible mediator between low SES and poor health (Van Cauter & Spiegel, 1999). Other identified risk factors of sleep problems comprise adverse health behavior (smoking, caffeine consumption, physical exercise) and high body mass index (Bixler, Kales, Soldatos, Kales, & Healey, 1979; Cirignotta, Mondini, Zucconi, Lenzi, & Lugaresi, 1985; Ito, Tamakoshi, Yamaki, Wakai, Kawamura, Takagi et al., 2000; Janson, Gislason, De Backer, Plaschke, Bjornsson, Hetta et al., 1995; Pi-Sunyer, 2002). Risk factors in the working environment are shift work (rotating schedules, early morning, late evening, night) and work under time constraints (assembly line or piece work) and these have been repeatedly linked to problems with sleep (Akerstedt, Knutsson, Westerholm, Theorell, Alfredsson, & Kecklund, 2002; Marquie, Foret, & Queinnec, 1999) for overview, see (Ribet & Derriennic, 1999). In a prospective study on 21,378 employees, Ribet and Derriennic (Ribet & Derriennic, 1999) found that objective occupational risk factors (shift work, work week > 48 hours, exposure to vibrations) and psychosocial occupational factors were associated with falling incidence of sleep complaints at five-year follow-up. Other investigators showed that poor work conditions were associated with sleep disturbances, such as high work demands (Akerstedt, Knutsson, Westerholm et al., 2002), job difficulty (Estryn-Behar, Kaminski, Peigne, Bonnet, Vaichere, Gozlan et al., 1990), physically strenuous work (Akerstedt, Fredlund, Gillberg, & Jansson, 2002; Akerstedt, Knutsson, Westerholm et al., 2002), and low social support from co-workers and supervisors (Akerstedt, Knutsson, Westerholm et al., 2002) (Jacquinet-Salord, Lang, Fouriaud, Nicoulet, & Bingham, 1993; Kageyama, Nishikido, Kobayashi, Kurokawa, Kaneko, & Kabuto, 1998). In summary, there is growing evidence that work stress, shift work, and physical workload are associated with sleep problems.

4 OBJECTIVES AND METHODS OF THE STUDIES

4.1 Study design

The present thesis is based on data obtained at entry of a longitudinal study on "Work and Health". Study participants were recruited from two airplane manufacturing plants in Southern Germany, both belonging to the EADS (European Aeronautic Defence and Space) Company. At the first site (Augsburg), the recruitment procedure followed a stratified random sampling strategy. Approximately half of the 2000 employees were invited to participate. At the second site (Manching), participation was offered to all employees. All participants were underwent the same study protocol. A total of 1847 subjects (plant Augsburg: n = 814, accrual rate = 41%; plant Manching: n = 1033, accrual rate = 57 %) volunteered to complete self-report questionnaires providing medical and psychosocial data (Figure 7). In addition to time spent, payed as working time, participating in the study and the option of personal health counseling by two study physicians, no other incentives were offered. Due to the employment structure of the company, the resulting samples predominantly consisted of men (about 89% males) between 15 and 64 years of age (mean 39.7 yrs. ± 11.3). The majority of the sample was qualified skilled workers (71%), other job positions were: foremen (14%), trainees (6%), about skilled workers (4%), and supervisors or managers (4%). Based on the characteristics of the study sample (preponderance of men, age range) the present population might be generally considered an at-risk-population. All subjects participated voluntarily and gave written informed consent. The ethic committees of the Swiss Federal Institute of Technology, Zurich, Switzerland, and the EADS Company have formally approved the study protocol.

Figure 7: Data collection



4.2 Objectives and hypotheses

On a general level, the objectives of this thesis were to:

- examine the relationship of ERI and OC to vital exhaustion;
- evaluate the current model on the basis of the interaction hypothesis that suggests that the effect of effort-reward-imbalance is moderated by overcommitment (vital exhaustion, health-related quality of life, depressed mood, and sleep quality);
- examine the relationship between effort-reward-imbalance and overcommitment to allostatic load; and,
- evaluate the model according to its underlying factorial structure.

On a specific level, the thesis` hypotheses were as follows:

- Effort-reward-imbalance and overcommitment are independent predictors of vital exhaustion (*Extrinsic ERI hypothesis and intrinsic overcommitment hypothesis).*
- Effort-reward-imbalance is a predictor of vital exhaustion, health-related quality of life, depressed mood, and sleep quality, while overcommitment moderates this relationship *(Interaction hypothesis)*.
- Effort-reward-imbalance is a predictor of allostatic load, while overcommitment

moderates this relationship *(Interaction hypothesis)*.

— The *structure* of the ERI model compromises the three factors ‘effort’, ‘reward’, and ‘overcommitment’, while reward is composed of the three subcomponents ‘money’, ‘esteem’, and ‘security’.

4.3 Methods

Table 4: Participants, predictor and criterion variables of the studies

Study	**I**	**II**	**III**	**IV**
Final Sample (N, mean age ± SD)	N=642 (89.6% male) Mean age (39.9 ± 10.7 yrs) Plant: Augsburg	N=1894 (86.8% male) Mean age (39.1 ±, SD 11.86 yrs) Plant: Augsburg, Manching	N=1588 (87 % male) Mean age (39.1 ±, SD 11.7 yrs) Plant: Augsburg, Manching	N=1588 (87 % male) Mean age (39.1 ±, SD 11.7 yrs) Plant: Augsburg, Manching
Predictor variables	Working conditions (ERI ERI, OC; SALSA questionnaire) Type D (Distressed) Personality Questionnaire (DS14) Depression (HADS-D) Control: Age, sex, SES (education, family status, position); shift work	ERI questionnaire (ERI, OC) Control: Age, sex, position, negative affectivity)	ERI questionnaire (ERI, OC) Control: Age, gender, alcohol intake, smoking, physical activity	ERI questionnaire (ERI, OC)
Criterion variable(s)	Vital exhaustion (Maastricht Vital Exhaustion Questionnaire)	Vital exhaustion (Maastricht Vital Exhaustion Questionnaire) Mental and physical health (SF12 questionnaire) Depression (HADS-D) Sleep quality (Jenkins sleep quality index)	Allostatic load: SBP, DBP; waist-to hip ratio; HDL, LDL, cholesterol, DHEA-S, Hb1Ac; cortisol, epinephrine, norepinephrin; CRP, micro-albuminuria, BMI, D-dimer, fibrinogen	For external validation: SF12 questionnaire (mental and physical health)

5 EMPIRICAL STUDIES

5.1 Study I: Overcommitment to work is associated with vital exhaustion

ABSTRACT

Objectives: Vital exhaustion has been shown to predict the progression and manifestation of cardiovascular disease. Little is known about the relationship between vital exhaustion and overcommitment, the inability to withdraw from obligations at work. The aim of this study was to explore the relationship between vital exhaustion and overcommitment at work, as measured by the intrinsic effort scale of the Effort-Reward Model after considering other potentially salutogenetic and pathogenetic working conditions.

Methods: This cross sectional study is based on a stratified random sample of 642 employees (mean age 39.9 years, standard deviation 10.7 years) from a manufacturing and assembly plant for airplane parts. Participants completed a questionnaire which included the nine-item shortened Maastricht Exhaustion Questionnaire to score the dependent variable exhaustion, and the six-item short form of the intrinsic effort scale ("immersion") of the Effort-Reward-Imbalance model as the primary independent variable. Perceived work stress was assessed by Siegrist's Effort-Reward-Imbalance questionnaire and the 52-item, 13 subscale salutogenetic subjective work assessment (SALSA) questionnaire, which focuses on indicators of perceived work stress in terms of pathogenetic and salutogenetic descriptors of decision latitude, psychological job demands and social support. Additional candidate covariates included depression, anxiety and Type D personality.

Results: In regression analysis, overcommitment ($r=.516$; $p<.0001$) was independently associated with vital exhaustion. Multivariable linear regression analysis showed that overcommitment explained 27% of the variance of vital exhaustion.

Conclusions: Overcommitment, indicating an exhaustive work-related coping style, is independently associated with vital exhaustion. It appears to be an important personality trait that may contribute to feelings of exhaustion at times of increased job strain.

Keywords: Vital exhaustion, overcommitment, effort-reward-imbalance, job stress, cardiovascular disease.

INTRODUCTION

The concept of vital exhaustion was introduced by Appels and coworkers to describe a psychological state characterized by excessive fatigue and lack of energy, demoralization, and increased irritability (Appels, 1997a; Appels & Mulder, 1989). Vital exhaustion has been identified as an independent risk factor for adverse health outcomes, including coronary artery disease (CAD) (Kop, Appels, Mendes de Leon et al., 1996). Excess fatigue and feelings of general malaise are among the most prevalent precursors of myocardial infarction and sudden cardiac death (Appels & Mulder, 1988; Cole, Kawachi, Sesso et al., 1999; Kop, Appels, Mendes de Leon et al., 1994). Vital exhaustion is also associated with depression (Kopp, Falger, Appels, & Szedmak, 1998; van Diest & Appels, 1991), Type D personality (Denollet, 2000; Pedersen & Middel, 2001), and with perceived work stress (Schnorpfeil, Noll, Wirtz et al., 2002). Our group has previously suggested that vital exhaustion should be considered as an indicator of the breakdown of adaptation to a chronically stressful working environment. However, the question as to what extent an individual's intrinsic disposition contributes to the risk of exhaustion was left unanswered in our previous work (Schnorpfeil, Noll, Wirtz et al., 2002).

Intrinsic components related to the individual pattern of coping with job demands were included in the Effort-Reward-Imbalance model suggested by Siegrist and coworkers (Siegrist, 2002b). Providing a conceptual framework, the model was introduced to explain the relation between work characteristics and adverse health outcomes in empirical research (de Jonge, Bosma, Peter et al., 2000; Siegrist & Peter, 2000; Siegrist, Starke, Chandola, Godin, Marmot, Niedhammer et al., 2004). The model posits that a lack of reprocity between costs and gains causes a state of emotional distress that, in the long run, may augment the risk of cardiovascular disease and other adverse health outcomes, like psychosomatic complaints (de Jonge, Bosma, Peter et al., 2000). The model distinguishes between situational ('extrinsic') and personal ('intrinsic') components. Extrinsic components include the rewards received at work offered to a worker as part of the social exchange process such as money, esteem, security or career opportunities. Psychological and physical demands at work are also understood to be of extrinsic quality. In contrast, the intrinsic or personal component 'overcommitment' stands for a specific, individual pattern of coping with the various job demands and eliciting rewards.

The term overcommitment defines a set of attitudes, behaviors and emotions reflecting a person's excessive striving for approval and appreciation. The model proposes that people who overcommit are exaggerating their efforts beyond levels usually considered appropriate, or they expose themselves to high demands at work too often. Consequently, these efforts diminish their potential to recover from job demands and increase their susceptibility to frustration when the expected rewards are not forthcoming, which eventually results in poor health (Siegrist, 2001). In support of the Effort-Reward-Imbalance model, cross sectional studies have demonstrated that overcommitment is associated with self-reported musculoskeletal pain (Joksimovic, Starke, v d Knesebeck et al., 2002), depression (Tsutsumi, Kayaba, Theorell et al., 2001), and cardiovascular risk factors (Vrijkotte, van Doornen, & de Geus, 1999).

The aim of the present study was to test the unique value of Siegrist's Effort-Reward-Imbalance model (Siegrist, Klein, & Voigt, 1997) in predicting vital exhaustion independently of other psychosocial risk factors for cardiovascular disease previously associated with vital exhaustion, namely Type D personality (Denollet, 2000) and depressed mood (Kopp, Falger, Appels et al., 1998; van Diest & Appels, 1991). Additional explanatory factors such as pathogenetic and salutogenetic work characteristics (Schnorpfeil, Noll, Wirtz et al., 2002) were included. In order to adjust for possible confounding effects, age, gender, educational level, family status, shift work, and job position were taken into account in multivariate regression analyses.

METHODS

Settings and Participants

In November 2002, a stratified, representative random sample of 1,117 employees from two European aircraft manufacturing plants was invited to participate in a research project termed "Health and Work". Out of these employees, 816 (73%) agreed to participate. No incentive was offered, yet time during participation was paid for as working time. If required, a personal feedback was given by two study physicians. Subjects with a positive history of CAD and cardiac surgery were excluded. The final sample consisted of 642 participants (90% male) with a complete data set of the variables of interest for allowing the full linear regression approach. Mean age of the sample was 39.9 years (SD 10.7). Mean employment time at the current plant was 15.4 (SD 11.4) years. Shift work was carried out by 29.3 % of the participants. Further characteristics of the sample are given in Table 1.

Table 1: Characteristics of the study population

Characteristics	N (SD)	Percent
Number of participants	642	
Gender (men/women)	575 / 67	89.6% / 10.4%
Mean age (SD) in years	39.86 (10.73)	
Mean duration (SD) of employment in years	15.43 (11.41)	
Shift work	188	29.3%
Position		
Supervisor or manager	29	4.5%
Forman	95	14.8%
Skilled workers	458	71.3%
Semi-skilled workers	25	3.9%
Trainees	35	5.5%
Educational level		
Primary school	9	1.4%
Lower secondary level	399	62.1%
Intermediate secondary level	144	22.4%
Vocational College / Higher secondary level	90	14.0%
Family status		
Single	190	29.6%
Married	416	64.8%
Divorced	35	5.5%
Widowed	1	0.2%

Study design

Cross sectional study. During a one-hour group session (10 – 25 individuals), each participant completed a set of questionnaires after a standardized oral introduction. Group sessions were held in a room detached from the working environment.

Measures

Vital exhaustion: Vital Exhaustion was assessed by means of the nine-item short form of the Maastricht Vital Exhaustion Questionnaire, which was derived from the original Maastricht questionnaire established by Appels and coworkers (Appels, Hoppener, & Mulder, 1987) (Appels & Mulder, 1988). The nine items asked about undue fatigue, troubles falling asleep, waking up at night, general malaise, apathy, irritability, loss of energy, demoralization, and waking up exhausted. For the purpose of this study the nine items were translated into the German language in cooperation with the authors of the original questionnaire (Schnorpfeil, Noll, Wirtz et al., 2002). In either versions of the original and the translated questionnaire, possible categories are “no”, scored as 0; “don’t know”, scored as 1; and “yes”, scored as 2, adding up to an overall score from 0 to 18.

Effort-reward: Extrinsic effort and reward at work are the main scales of the model of Effort-Reward-Imbalance by Siegrist and coworkers (Siegrist, 2002b). Extrinsic effort is measured by six items that refer to demanding aspects of the work environment. Items are answered in two steps. First, subjects agree or disagree on whether or not the item content describes a typical experience of their work situation. Subsequently, subjects who agreed on one item are asked to evaluate to what extent they usually feel distressed by this experience. The rating procedure is defined as follows: 1=”does not apply”, 2=”does apply, but not distressed”, 3=”does apply and somewhat distressed”, 4=”does apply and distressed”, 5=”does apply and very distressed”. Reward is measured accordingly effort by 11 items although the coding is reversed. Therefore, the lower the summary score for reward, the lower the subjectively experienced reward at work and the higher the ratings of distress due to low reward. The ratio of effort (numerator) and reward (denumerator) is quantifying the amount of effort-reward-imbalance.

Overcommitment: Overcommitment at work was assessed with the six-item short form of the intrinsic effort scale (“immersion”) of the Effort-Reward Model (Siegrist, 2002b). On a four-point rating scale, subjects indicated to what extent they personally agree or disagree with the given statements. The short form focuses on the “inability to withdraw from work” (5 items) and “disproportionate irritability” (1 item).

Short version of the Overcommitment Questionnaire

	Please indicate to what extend you personally agree or disagree with the following statements. (1=strongly disagree, 2=disagree, 3=agree, 4=strongly agree)
No.	Item
1	I get easily overwhelmed by time pressures at work.
2	I start thinking about work problems as soon as I get up in the morning.
3	When I get home, I can easily relax and forget all about work.
4	People close to me say I sacrifice too much for my job.
5	Work is usually still on my mind when I go to bed.
6	If I put off something that needs to be done today, I'll have troubles sleeping at night.

Work characteristics:

The conditions of the working environment were assessed by using the salutogenetic subjective work assessment (SALSA) (Rimann & Udris, 1997). The SALSA questionnaire assesses the subjective perception of work characteristics. This instrument has been validated on German industrial workers with a cultural background similar to that of the target population. Based on the 52 items of the SALSA the following 13 scales are derived: wholeness of work tasks (three items), responsibility and required qualification (four items), task variety (three items), qualification potential (three items), decision authority (three items), extent of participation (three items), excessive workload or qualitative demands (five items), lack of qualitative demands (three items), social support of co-workers (four items), supportive supervisor behavior (four items), adverse co-worker behavior (three items), adverse supervisor behavior (three items) and adverse physical work conditions (11 items). Conceptually, the SALSA scales comprise pathogenetic and salutogenetic descriptors of decision latitude, psychological job demands and social support given by supervisors and co-workers.

Depressive Mood: Depressive mood was measured by the depression subscale of the Hospital Anxiety and Depression Scale (HADS), a 14-item self-report screening tool originally developed to measure the severity of anxious and depressed mood (Zigmond & Snaith, 1983). The HADS avoids statements referring to symptoms that may have a physical cause (e.g. weight loss, insomnia). The depression subscale of the HADS (HADS-D) consists of seven items. Answers are coded on a four-point Likert scale ranging from 0="mostly" to 3="not at all". We applied the recently validated German version (Herrmann, Buss, & Snaith, 1995).

Type D (Distressed) Personality Questionnaire (DS14): The Type D Personality Questionnaire was applied to assess the tendency to experience distress (Denollet, 2000; Denollet & Brutsaert, 1998; Denollet & Van Heck, 2001). Following this concept the combination of high negative affectivity and high social inhibition designates a Type D personality. Negative affectivity is defined as the tendency to experience aversive emotional states (dysphoria, depressed mood) and feelings of tension and worry. Social inhibition is defined by the tendency to inhibit self-expression in social interaction (reticence and withdrawal). Negative affectivity is associated with vulnerability to clinically relevant depression and anxiety, and social inhibition with interpersonal stress. We applied the German version, recently validated by Herrmann-Lingen and coworkers (Herrmann-Lingen, Grande, Jordan, & Denollet, 2002). According this version, the two subscales negative affectivity and social inhibition are composed of seven items each and subjects' responses are coded on a five-point rating scale ranging from 0 to 4.

Statistical analysis

The data analyses are based on those participants who provided a complete data set in terms of the variables vital exhaustion, age, sex, education level, family status, position, shift work, Type D personality, depression, overcommitment, effort-reward, and SALSA variables. As the first step, the potential association between vital exhaustion, effort-reward-imbalance, and overcommitment was analyzed by partial correlation analyses accounting for baseline demographic variables and risk factors for vital exhaustion (e.g. Type D personality, depression). Secondly, we applied stepwise multivariable regression models with vital exhaustion score as the dependent variable and overcommitment and effort-reward-imbalance scores as independent variables. Type D personality, depressed mood, and work characteristics, as measured by the SALSA questionnaire, were included as candidate confounders. Variables showing no significant associations ($p>.05$) with vital exhaustion in univariate analyses (Spearman) were excluded from multivariate approach. All analyses were performed using SPSS version 11.0 (SPSS Inc., Chicago, IL).

RESULTS

Following previous criteria (Schnorpfeil, Noll, Wirtz et al., 2002), 140 (21.8%) subjects in that sample were classified as not being exhausted (vital exhaustion scores between 0 and 2), 311 (52.3%) subjects were mildly to moderately exhausted (vital exhaustion scores between 3 and 10), and 191 (25.9%) subjects showed severe (i.e., “clinical”) exhaustion (vital exhaustion scores 11).

Relation between the vital exhaustion score and effort-reward and overcommitment

Firstly, we tested bivariate associations between vital exhaustion and demographic and psychosocial factors. Table 2 shows that the majority of these correlations were statistically significant. The highest correlation coefficients emerged in the associations between vital exhaustion and Type D personality (r=.57), depression (r=.57), excessive workload (r=.37), adverse co-worker behavior (r=.40), adverse physical conditions (r=.34), and, of particular interest, overcommitment (r=.52) and effort-reward-imbalance (r=.45). Correlation analyses adjusted for demographic variables and Type D personality and depressed mood rendered essentially the same results.

Table 2: Unadjusted and adjusted bivariate correlation analyses between vital exhaustion and work characteristics

Vital exhaustion	Simple Pearson correlation		Partial correlation controlling for Variables 1) - 8)	
Variable				
1) Age	.074	p = .060		
2) Sex	-.049	p = .212		
3) Education level	-.095	p = .016		
4) Family status	.039	p = .329		
5) Position	.002	p = .955		
6) Shift work	.124	p = .002		
7) Type D Personality	.574	p < .001		
8) Depression (HADS)	.574	p < .001		
9) Overcommitment	.516	p < .001	.384	p < .001
10) Effort-reward imbalance	.453	p < .001	.547	p < .001
11) SALSA subscales:				
Wholeness of working task	-.141	p < .001	-.140	p < .001
Responsibility, required qualification	-.086	p = .030	-.067	p = .092
Task variety	-.145	p < .001	-.128	p = .001
Qualification potential	-.251	p < .001	-.214	p < .001
Decision authority	-.169	p < .001	-.15	p < .001
Extent of participating	-.302	p < .001	-.278	p < .001
Excessive workload, qualitat. demands	.369	p < .001	.373	p < .001
Lack of qualitative demands	.204	p < .001	.193	p < .001
Social support by co-workers	-.256	p < .001	-.249	p < .001
Supportive supervisor behavior	-.298	p < .001	-.276	p < .001
Adverse co-worker behavior	.399	p < .001	.401	p < .001
Adverse supervisor behavior	.319	p < .001	.305	p < .001
Adverse physical conditions	.339	p < .001	.316	p < .001

Multivariable regression models

Sequential linear regression analyses contained six independent variables, which together explained 52% of the observed variance of vital exhaustion. Namely, these variables were depression, overcommitment, Type D personality, decision authority, effort-reward-imbalance, and adverse physical conditions. Effort-reward-imbalance and overcommitment were entered in a final step. When overcommitment was entered as the first variable, this scale explained 27% of the variance in vital exhaustion scores. When adding overcommitment as the last variable to the fully adjusted model, it still explained an additional 4% variance in vital exhaustion. Table 3 shows the results of the multivariable model.

Table 3. Final model of multivariable linear regression analyses for vital exhaustion

Model Summary			
Sequential regression analysis	**ß**	**p**	**r^2 change**
Type D personality	.297	$p < .001$	.33
Overcommitment	.263	$p < .001$	.11
Depression (HADS-D)	.230	$p < .001$	.05
SALSA decision authority	-.107	$p < .001$	.02
Effort-reward-imbalance	.088	$p = .010$	.01
Adverse physical conditions	.078	$p = .013$	.005
Total model		**Adjusted r^2 =** .518	

Notes: HADS-D = Depression subscale of the Hospital Anxiety and Depression Scale;
ERI = Effort-reward-imbalance (ratio); SALSA = salutogenetic subjective work analysis

DISCUSSION

Overcommitment has been defined as a personality trait characterized by the inability to disengage oneself cognitively, emotionally, and behaviorally from obligations imposed by the work environment. The present study suggests that overcommitment at work is associated with vital exhaustion, a mental state that has been shown to predict events of cardiovascular disease (Appels & Mulder, 1988; Cole, Kawachi, Sesso et al., 1999; Kop, Appels, Mendes de Leon et al., 1994). Notably, the association between overcommitment and exhaustion was independent of Type D Personality and severity of depressed mood, which were both found to be correlates of vital exhaustion in previous studies (Pedersen & Middel, 2001; Wojciechowski, Strik, Falger, Lousberg, & Honig, 2000). Other work characteristics (i.e., decision authority, effort-reward-imbalance, shift work), although independently associated with exhaustion in our study, only partially moderated the relation between overcommitment and vital exhaustion. While overcommitment may be of an advantage in coping with adverse work characteristics by leading to adaptation to the stressful situation, it may become maladaptive if it confers a rigid coping style that fails to bring relieve from job strain.

It has previously been suggested that overcommitment shows a close overlap with the Type A coronary behavior pattern (Vrijkotte, van Doornen, & de Geus, 1999). Type A individuals exhibit personality features characterized by excessive drive, competitiveness, rapid work pace, and the inability to relax (Friedman & Rosenman, 1959). In the early 1980's, an independent review panel approved Type A behavior to be a risk factor for CAD (The Review Panel on Coronary-Prone Behavior and Coronary Heart Disease, 1981). However, subsequent studies largely failed to find such a relationship, and, to date, there remains little evidence that Type A personality is an independent risk factor for CAD (Hemingway & Marmot, 1999). In spite of this dampened enthusiasm in Type A research, the call for a refinement of the Type A construct (Williams, 1987) has burgeoned an impressive amount of literature on anger and hostile personality traits, which are now both viewed as the "toxic" components of Type A (Rozanski, Blumenthal, & Kaplan, 1999). In this light, overcommitment might be another "toxic" ingredient of the Type A personality. Indeed, various characteristics of job stress have been related to increased risk of cardiac disease (Bosma, Marmot, Hemingway et al., 1997; Hemingway & Marmot, 1999).

Our findings ultimately relate to health prevention at the work place. More precisely, intervention strategies may be derived from the acknowledgement of the association between overcommitment and exhaustion before a state of vital exhaustion occurs. Individuals who commit themselves to work demands in a disproportional manner might benefit from cognitive-behavioral therapy at an early stage of perceived job strain. Preventive interventions might assist people to adopt more favorable coping patterns when exposed to stressful work circumstances, as well as to reflect on the ideas and assumptions driving overcommitment. While a certain degree of overcommitment is welcomed from the supervisors' or business owners' perspective, our data suggest that this personal trait puts individual at an increased risk of exhaustion and possibly burnout. Thus, human resource management should be particularly aware of signs heralding exhaustion in their overcommitted staff, because otherwise it may spiral into a full burnout syndrome.

The primary limitation of our study is the cross sectional nature of the data, which does not permit causal conclusions regarding the direction of the overcommitment-exhaustion-relationship. However, it appears unlikely that exhaustion would cause individuals to exhibit exaggerated commitment at work. It is more likely that overcommitment renders individuals more susceptible to exhaustion. A further limitation relates to the dearth of longitudinal data elucidating the biological pathways linking overcommitment to adverse health outcomes. Hence, assessing the long-term impact of the overcommitment-exhaustion pathway requires longitudinal studies. One of the strengths of this study is the rather extensive list of independent variables considered describing work characteristics and personality traits, which have been related to adverse health outcomes in the past (e.g. Type D personality). Thus, it is unlikely that relevant variables, that would have unraveled the observed association between exhaustion and overcommitment, remained unconsidered.

Summarizing our findings, we demonstrated that a personal style to cope with adverse work characteristics, namely overcommitment, is independently associated with vital exhaustion. This extends our previous work based on the same population (Schnorpfeil, Noll, Wirtz et al., 2002) that demonstrated an association between work characteristics and exhaustion. We suggest that the six-item overcommitment scale is used as a screening instrument in future assessments of work characteristics and employee health.

5.2 Study II: Effort-reward-imbalance, overcommitment and self-reported health: It’s the interaction that matters most.

ABSTRACT

Background: In recent years, the effort-reward-imbalance (ERI) model has become a widely used framework to examine job characteristics and health.

Aim: To examine the relative contribution of the components of the ERI model – effort-reward imbalance and overcommitment – to the explanation of impaired health-related quality of life, sleep problems, increased risks of vital exhaustion, and depressed mood in a highly competitive industry.

Subjects: In a cross-sectional study, data were obtained from 1,894 employees (mean age 39.7, SD 11.86 years; 86.8% male) from two separate production plants in the airplane manufacturing industry in Southern Germany.

Methods: Participants were split into four groups, in which high and low overcommitment was combined with high and low effort-reward imbalance. Univariate regression analyses with dummy encoding were used.

Results: Subjects reporting high effort-reward imbalance or high overcommitment had a decreased health-related quality of life and higher risks of sleep problems, vital exhaustion, and depressive mood (standardized beta coefficients ranged from |0.22| to |0.49| SD). As to importance, standardized beta coefficients were generally higher in those employees reporting both high imbalance between effort and reward and overcommitment (SD ranged from |0.46| to |1.14|). Interaction between perceived imbalance and high overcommitment tends particularly to predict vital exhaustion (1.11 SD), depressed mood (0.94 SD), and SF12 mental health (0.90 SD).

Conclusion: Our findings highlight the predictive validity of the effort-reward model on employees’ health. Although the cross-sectional design does not allow conclusions as to causality, the data suggests that the interaction of effort-reward imbalance and overcommitment is the strongest risk factor of poorer self-reported health in terms of health-related quality of life, sleep problems, vital exhaustion and depressed mood.

Keywords: Psychosocial factors at work, effort-reward imbalance, overcommitment, self-reported health.

INTRODUCTION

Numerous longitudinal studies support the claim that there is an inverse relationship between an unfavorable psychosocial work environment and employee health and well-being (Blane, 1999; Hemingway & Marmot, 1999; Karasek & Theorell, 1990b; Krantz & McCeney, 2002; Levi, Bartley, Marmot et al., 2000; Rozanski, Blumenthal, & Kaplan, 1999; Siegrist, 2002b). Several theoretical frameworks have been proposed to conceptualize specific job characteristics and their impact on health outcomes in working populations (Levi, Bartley, Marmot et al., 2000; Semmer & Mohr, 2001). Two models have emerged that allow us to operationalize the relationship between job stress and adverse health outcomes: the job-strain model (Karasek, 1979; Karasek & Theorell, 1990b), identifying 'job demands', 'job control' and 'social support' as critical dimensions of the working environment, and the effort-reward-imbalance (ERI) model (Siegrist, 1986, 1996; Siegrist, 2002b). The ERI model postulates that jobs characterized by poor reciprocity between efforts ('costs') spent and rewards ('gains') received at work are likely to elicit recurrent feelings of emotional distress. According to theoretical assumptions, the associated autonomic arousal and neuroendocrine stress responses may eventually lead to the observed adverse long-term effects on employees' health (Siegrist 2002).

Within the past decade, a number of studies have consistently shown effort-reward imbalance to be a risk factor for cardiovascular diseases (Bosma, Peter, Siegrist et al., 1998; Kuper, Singh-Manoux, Siegrist et al., 2002; Niedhammer, Goldberg, Leclerc et al., 1998b; Peter & Siegrist, 1999, 2000; Siegrist, Peter, Junge et al., 1990) and changes in cardiovascular risk parameters (Peter & Siegrist, 1997; Siegrist, Peter, Cremer et al., 1997; Vrijkotte, van Doornen, & de Geus, 2000). Other health indicators were also demonstrated to relate to effort-reward imbalance, like self-reported health (Godin & Kittel, 2004; Niedhammer, Tek, Starke et al., 2004; Pikhart, Bobak, Siegrist et al., 2001; Stansfeld, Bosma, Hemingway et al., 1998), poor well-being (de Jonge, Bosma, Peter et al., 2000), depression (Pikhart, Bobak, Pajak et al., 2004; Tsutsumi, Kayaba, Theorell et al., 2001), and musculoskeletal pain (Joksimovic, Starke, v d Knesebeck et al., 2002); for an overview, see Siegrist (Siegrist, 2002b).

Besides effort-reward imbalance the ERI model explicitly conceptualizes a personal characteristic related to coping with demands and reward, named overcommitment. According to the model, employees characterized by a motivational pattern of excessive overcommitment at work and a strong need for approval are particularly compromised by recognizing a negative trade-off between high effort and low reward. Hence, highly overcommitted workers misjudge the balance between the demands at work and their own resources for coping with them (Siegrist, 1996). Underestimating the external demands and overestimating the own coping resources bears the risk of prolonged exposure to non-reciprocal exchange (Siegrist, 1996; Siegrist, 2002b).

Few studies have linked overcommitment with cardiovascular health (Bosma, Peter, Siegrist et al., 1998) and risk factors, like an impaired fibrinolytic system (Vrijkotte, van Doornen, & de Geus, 1999), or other health indicators, such as musculoskeletal pain (Joksimovic, Starke, v d Knesebeck et al., 2002), depression (Tsutsumi, Kayaba, Theorell et al., 2001), psychosomatic complaints (Godin & Kittel, 2004), and self-reported health in men (Niedhammer, Tek, Starke et al., 2004).

From a theoretical point of view it is of particular interest that the ERI model encompasses not only situational, work-related dimensions (effort, rewards), but it also includes personal characteristics, i.e. the motivation and ability to cope with a situation (overcommitment). According to the effects of the model's components, it is postulated that:

- The mismatch between high effort and low reward produces adverse health effects. This structural component is considered as what "matters most" (Siegrist, 2002b), p. 266).
- A high level of overcommitment acts as a trigger for non-reciprocal exchange, resulting in negative effects on health.
- If both structural and personal components operate simultaneously, the strongest effects on health and well-being are expected to occur.

While effort-reward imbalance is now considered to be a significant risk factor of the development of stress-related diseases (model's first prediction) (Bosma, Peter, Siegrist et al., 1998; Joksimovic, Starke, v d Knesebeck et al., 2002; Kivimaki, Leino-Arjas, Luukkonen et al., 2002; Kuper, Singh-Manoux, Siegrist et al., 2002; Stansfeld, Bosma, Hemingway et al., 1998), the application of the full, recommended version of the ERI model, including the personal factor 'overcommitment' is less common. In most studies, the two components were not used simultaneously or, if so, a crude proxy measure of overcommitment was applied, for review see (Siegrist, 2002b; Tsutsumi & Kawakami, 2004; van Vegchel, de Jonge, Bosma et al., 2004). Hence, the interaction of both situational and personal characteristics requires further elucidation.

The aim of the present study was to test predictive validity of the full, recommended effort-reward model, including both structural and personal components, within a comprehensive assessment of self-reported health. We analyzed five different outcome variables: Health-related physical and mental quality of life, sleep, vital exhaustion, and depressed mood. In recent years, health-related quality of life has become a promising outcome measure in occupational stress research (Amick, Kawachi, Coakley et al., 1998; Cheng, Kawachi, Coakley et al., 2000; Stansfeld, Bosma, Hemingway et al., 1998; Stansfeld, Head, Fuhrer, Wardle, & Cattell, 2003). Extensive literature provides evidence that psychological factors contribute significantly to the pathogenesis of cardiovascular disease, for review, see (Hemingway & Marmot, 1999; Krantz & McCeney, 2002; Rozanski, Blumenthal, & Kaplan, 1999). Being one of these, vital exhaustion has been identified as an independent risk factor for adverse health outcomes, including cardiovascular disease (Appels, Kop, Bar et al., 1995; Appels, Kop, & Schouten, 2000; Kop, Appels, Mendes de Leon et al., 1996; Kop, Appels, Mendes de Leon et al., 1994; Kop, Hamulyak, Pernot et al., 1998). Excess fatigue and feelings of general malaise are among the most prevalent precursors of myocardial infarction and sudden cardiac death (Appels & Mulder, 1988; Kop, Appels, Mendes de Leon et al., 1994). Numerous epidemiological studies have demonstrated a significant prospective relationship between the occurrence of major depression and the number of cardiac events (Kop, Appels, Mendes de Leon et al., 1994). Even minor depressive symptomatology is associated with an increased risk of cardiac events, suggesting a gradient relation between depression scores and risk of cardiovascular disease (Rozanski, Blumenthal, & Kaplan, 1999).

In sum, this study intends to examine the relative contribution of the ERI model's components to the explanation of enhanced risks for employees regarding these aspects of self-reported health. We hypothesized that non-reciprocal working conditions are harmful for workers' health and well-being, but it's the combination of personal and situational factors that “matters most”.

METHODS

Settings and Participants

Participants were recruited from two successive enrolment periods in the ETH cohort project at two separate production plants of the EADS airplane manufacturing industry in Southern Germany. At the first study site, a stratified, representative random sample of the 1,117 employees was invited to participate in a research project termed “Health and Work”. Of these employees, 816 (73%) agreed to participate. No incentive was offered, but time for participation was paid as working time, and, if desired, a personal feedback was given by two study physicians. At the second study site, all permanent employees (n = 1802) were invited to partake in the study. Of these, 1,094 (61%) participated. Sample characteristics are presented in Table 1a.

Measurements

Effort-reward imbalance was measured by the full, recommended scales of the ERI model developed by Siegrist and coworkers (Siegrist, 2002b). Effort is measured by six items that refer to demanding aspects of the work environment. The scores for effort can vary from 6 to 30. Items are answered in two steps. First, subjects agree or disagree on whether or not the item content describes a typical experience in their work situation. Subsequently, subjects who agree are asked to evaluate to what extent they usually feel distressed by this experience. The rating procedure is defined as follows: 1=”does not apply”, 2=”does apply, but not distressed”, 3=”does apply and somewhat distressed”, 4="does apply and distressed", 5="does apply and very distressed". Reward is measured according to effort by 11 items although the coding is reversed. Therefore, the lower the summary score for reward, the lower the subjectively experienced reward at work and the higher the ratings of distress due to low reward. The score for reward can vary from 11 to 55. The ratio of effort (numerator) to reward (denominator) expresses the amount of effort-reward imbalance. It was calculated with the formula "effort/(c*reward)", adding up to an overall score ranging from 0.2-5.0. In the formula 'c' is a correction factor for different maximum numbers of items in the numerator and denominator. The internal reliability for effort (Cronbach's α) in the present study was 0.72, for reward 0.85.

Overcommitment was assessed with the six-item short form of the intrinsic effort scale ("immersion") of the effort-reward model (Siegrist, 2002b) (Niedhammer, Tek, Starke et al., 2004). This short form was developed from the 29-item original version, including those items that had the most impact in explaining health risks in prospective epidemiologic studies (Siegrist, 2002b). On a four-point rating scale, subjects indicate to what extent they personally agree or disagree with the given statements. The short form focuses on the "inability to withdraw from work" (5 items) and "disproportionate irritability" (1 item). The scores for overcommitment can vary from 6 to 24, the Cronbach's α for the overcommitment score was 0.81. On the basis of overcommitment and imbalance median splits, subjects were classified into high and low groups.

Self-reported health

Vital exhaustion (VE) was assessed by means of the nine-item short form of the Maastricht Vital Exhaustion Questionnaire, which was derived from the original Maastricht questionnaire established by Appels and coworkers (Appels, Hoppener, & Mulder, 1987). In detail, the nine items asked about undue fatigue, trouble falling asleep, waking up at night, general malaise, apathy, irritability, loss of energy, demoralization, and waking up exhausted. Possible answers are "no", scored as 0; "indeterminate", which is scored as 1; and "yes", scored as 2, giving rise to a score ranging between 0 and 18. We applied the German translation previously used by our group (Schnorpfeil, Noll, Wirtz et al., 2002). Internal reliability was Alpha=0.84.

Depressed mood was assessed by the depression subscale of the Hospital Anxiety and Depression Scale (HADS), a 14-item self-report screening tool originally developed to detect clinical anxiety or depressed mood (Zigmond & Snaith, 1983) within the general population. The HADS avoids statements referring to symptoms that may have a physical cause (e.g., weight loss, insomnia). The depression subscale of the HADS (HADS-D) consists of seven items. Answers are coded on a four-point Likert scale ranging from 0="mostly" to 3="not at all". We applied the recently validated German version (Herrmann, Buss, and Snaith, 1995). The score for HADS-D scale can vary from 0 to 21, reliability (Cronbach's α) was 0.76.

Quality of sleep was measured by the Jenkins sleep quality index (Jenkins, Stanton, Niemcryk, & Rose, 1988). The scale comprises four items focusing on the most common sleep problems ("difficulties falling asleep", "waking up during the night", "waking up having difficulties falling asleep again", "waking up tired"). Items are rated on a six-point scale, indicating how often the stated condition occurred during an average month ("not at all", "up to 3 days a month", "4-7 days a month", "8-14 days a month", "15-21 days a month", "22-31 days a month"). The scores for sleep quality can vary from 0 to 20, the Cronbach's α was 0.80.

Health-related quality of life or 'subjective health' was assessed by the German short version of the SF36 health survey (Bullinger, 1995; Bullinger & Kirchberger, 1998; Ware, Kosinski, & Keller, 1996). The SF36 as well as its short form SF12 has proved to be a psychometrically robust and practicable instrument for use in outcome evaluation of subjective health functioning in different countries and a wide range of populations (Bullinger, 1996; Bullinger & Kirchberger, 1998; Gandek, Ware, Aaronson, Apolone, Bjorner, Brazier et al., 1998). The 12-item SF12 is a self-report form of subjective health which assesses the dimensions: physical functioning, role limitations due to physical/emotional health problems, freedom from bodily pain, general health perception, vitality, social functioning, and mental health. From these eight dimensions a physical and a mental summary health score can be calculated following the scoring algorithm outlined in the manual, rendering scores with a mean of 50±10 (SD). The lower the resulting summary score, the lower self-reported subjective health functioning. Reliability (Cronbach's α) for mental health was 0.78, for physical health 0.78.

Statistical Analysis

In order to test the theoretical notions of the ERI model, we conducted a median split to define separate groups with high or low overcommitted subjects, as well as groups with high or low effort-reward ratio scores. Accordingly, four groups were computed by creating four independent categories: (1) low imbalance and low overcommitment (2) low imbalance and high overcommitment (3) high imbalance and low overcommitment, and (4) high imbalance and high overcommitment.

To justify multivariate definition of self-reported health, the correlations of outcome variables were analyzed first. In the second step, effects and interactions between the ERI model and any of the five outcome measures were tested for statistical significance in a multivariate model, including controlling for potential confounders (age, gender, and job position). In a further step, we conducted regression analyses to determine the associations between the four subcategories with measurements of self-reported health as dependent variables. These subcategories were represented by dummy indicators in the analysis. All analyses were performed using the SAS statistical software package (version 8.2, SAS Institute, Cary, NC, USA) or the SPSS statistical software package (version 11.0; SPSS Inc., Chicago, IL, USA).

RESULTS

Population

The present analysis is based on 1,894 employees with valid (non-missing) data on effort-reward imbalance and overcommitment. Mean age was 39.7 ± 11.86 years (age range 16 – 64 years). The majority of participants was male and qualified skilled workers (Table 1a). About thirty percent of the participants stated that they experienced imbalance at work and were overcommitted, about thirty-eight percent reported having neither an imbalanced work situation nor a high overcommitment coping style. The combination of high overcommitment and low imbalance was most likely to be reported among supervisors and senior managers (36.6%). The majority of the foremen (41.7%) reported high imbalance status and high overcommitment, whereas the favorable combination of low overcommitment and low imbalance was more likely to be experienced by subjects with lower job status, especially trainees (see Table 1a). About 12% of employees reported working under conditions of imbalance (ERI score >1).

Table 1a: Sample characteristics

		Low imbalance		High imbalance	
	Total (%)	**Low OC (%)**	**High OC (%)**	**Low OC (%)**	**High OC (%)**
Gender					
Female	238 (13.2%)	101 (42.4%)	33 (13.9%)	24 (10.1%)	80 (33.6%)
Male	1565 (86.8%)	590 (37.7%)	176 (11.2%)	331 (21.2%)	468 (29.9%)
Total (valid)	1803(100%)	691 (38.3%)	209 (11.6%)	355 (19.7%)	548 (30.4%)
Job Position					
Senior manager	82 (4.4%)	23 (28.0%)	30 (36.6%)	6 (7.3%)	23 (28.0%)
Foremen	223 (11.9%)	61 (27.4%)	43 (19.3%)	26 (11.7%)	93 (41.7%)
Qualified workers	1392 (74.1%)	508 (36.5%)	134 (9.6%)	319 (22.9%)	431 (31.0%)
Unskilled workers	61 (3.2%)	24 (39.3%)	4 (6.6%)	9 (14.8%)	24 (39.3%)
Trainees	121 (6.4%)	104 (86.0%)	3 (2.5%)	10 (8.3%)	4 (3.3%)

Dependent variables (health outcomes)

Compared to the SF12 German norm population (n=2914, age 14 to over 70 years) the analyzed sample had slightly lower physical summary scores (present study: 47.94 ± 7.86; norm population: 49.03 ± 9.35) and also lower mental summary scores (present study: 47.89 ± 9.76; norm population: 52.24 ± 8.1). Further descriptions of the outcome variables are provided in Table 1b.

Table 1b: Description of outcome variables

	Mean (SD)	Median (IQR)
Effort-reward imbalance	0.67 (± 0.31)	0.60 (0.47-0.79)
Overcommitment	13.78 (± 3.75)	14.00 (11.00-16.00)
Physical health (SF12)	47.94 (± 7.86)	52.26 (46.59-55.41)
Mental health (SF12)	47.89 (± 9.76)	50.75 (42.30-55.45)
Vital Exhaustion	7.53 (± 5.12)	7.00 (3.00-12.00)
Depressed mood	4.86 (± 3.23)	4.00 (2.00-7.00)
Sleep Quality	5.36 (± 4.28)	4.00 (2.00-8.00)

Table 2 shows the intercorrelations between the four outcome variables. A confirmatory factor analysis using a varimax rotation with Kaiser Normalization yielded two factors, which explained 75.83% of the variance. These two factors could be characterized as mental health and well-being (explaining 55.23%) and physical health and well-being (20.6% of the variance). Thus, from a statistical perspective there is evidence that there are two separate factors underlying the indicators for self-reported health used in this study. However, it has been recently argued that HADS-D, vital exhaustion, and the SF12 health survey show some conceptual overlap but are distinct psychological concepts (Kudielka, von Kanel, Gander, & Fischer, 2004).

Table 2: Intercorrelations between the four outcome variables

	Physical health (SF 12)	Mental health (SF 12)	Vital Exhaustion	Depressed mood	Sleep Quality
Physical health (SF12)	**.784**				
Mental health (SF12)	-.020	**.780**			
Vital Exhaustion	-.330**	-.625**	**.835**		
Depressed mood	-.277**	-565**	.596**	**.761**	
Sleep Quality	-.287**	-.396**	.654**	.428**	**.798**

Note: **Correlations are significant at the 0.01 level (2-tailed). Bold numbers: Cronbach's α.

Multivariate statistics and outcomes across median split of effort-reward imbalance and overcommitment

Mean values for the outcome variables SF12 mental and physical sum scores, vital exhaustion, HADS-D depression and Jenkins sleep quality index stratified by effort-reward imbalance/over-commitment subgroup are presented in Table 3. Multivariate statistics revealed significant effects for all groups except the low-imbalance and low-overcommitment group (all F (5.565) > 11.0, all p < 0.001). The low-imbalance, low-overcommitment group had the most favourable values in terms of self-reported health and well-being. Compared to this reference group, changes in the low-imbalance/high-overcommitment subjects ranged from 0.22 standard deviations (SD) (mental health) to 0.49 SD (exhaustion). In the high-imbalance/low-overcommitment group scores differed from about 0.27 SD (sleep) to 0.48 SD (exhaustion). In the subjects reporting high imbalance and high overcommitment we found a significant and noticeable shift in all measures of subjective health, ranging from -0.46 SD (physical health), 0.82 SD (sleep), -0.90 SD (mental health), and 0.94 (depressed mood), to 1.14 SD (vital exhaustion). All changes were statistically significant at $p < 0.001$.

Table 3: Means of dummy regression (Means)

	Low imbalance		High imbalance			
	Low OC[1]	High OC	Low OC	High OC	F	P
Physical health (SF12)[2]	51.76 (51.3)	49.54 (49.5)	49.52 (49.7)	48.17 (49.7)	21.77	< .0001
Mental health (SF12)[2]	51.33 (48.9)	49.16 (48.3)	48.21 (46.7)	42.51 (44.0)	92.52	< .0001
Vital Exhaustion	4.88 (6.4)	7.39 (8.1)	7.33 (8.3)	10.86 (10.3)	162.38	< .0001
Depressed mood	3.52 (4.3)	4.51 (4.5)	4.84 (5.0)	6.56 (5.6)	101.93	< .0001
Sleep Quality	3.82 (4.9)	5.54 (6.1)	4.95 (5.7)	7.32 (7.0)	76.15	< .0001

Notes: [1]Reference group in dummy regression analysis. [2] The higher the resulting summary scores, the higher is the self-reported subjective health functioning. Least square means estimates from generalized linear models adjusting for age, gender, education (socio-economic status), and negative affectivity are presented in parenthesis.

The results for dummy regression analysis controlling for job position are shown in Table 4. Compared to the reference group, vital exhaustion scores were significantly higher in the high-imbalance/high-overcommitment group across all job positions. In the latter group, scores in vital exhaustion deviated between 1.11 SD and 1.67 SD from the reference group.

Table 4: Results of the dummy regression for vital exhaustion and 95% Confidence Intervals (CIs), controlled for job position.

	Low imbalance		High imbalance	
	Low OC[1]	High OC	Low OC	High OC
Job position				
Senior manager	2.67	0.40	0.16	1.59***
Foremen	3.98	0.38*	0.38	1.28***
Qualified workers	4.99	0.62***	0.49***	1.117***
Unskilled workers	4.32	–	0.81*	1.67***
Trainees	5.41	–	0.80	–

Note: [1]Data in this column represent the means of the reference group in dummy regression analysis. *<.05 ***<.001. (–) presented in table only if n>5.

Table 5 represents the results of dummy regression analysis in self-rated mental health. Again, the largest deviations in comparison to the low-imbalance/low-overcommitment group were found in highly overcommitted participants with high imbalance status. Standardized beta coefficients range from -0.87 (qualified workers) up to -1.15 (unskilled workers).

Table 5: Results of the dummy regression for mental health (SF12), controlled for position.

	Low imbalance		High imbalance	
	Low OC[1]	High OC	Low OC	High OC
Position				
Senior manager	52.41	-0.01	0.25	-1.11***
Foremen	53.64	-0.25	-0.20	-1.09***
Qualified workers	51.17	-0.29*	-0.34***	-0.87***
Unskilled workers	52.35	–	-0.13	-1.15***
Trainees	50.49	–	-0.88*	–

Note: 1Data in this column represent the means of the reference group in dummy regression analysis.
*<.05 ***<.001. (–) presented in table only if n>5.

Dummy regression analyses adjusting for sociodemographic variables (age, gender, education), and negative affectivity rendered essentially the same results as presented in Table 3 in parenthesis.

DISCUSSION

The present study examined the interaction between effort-reward imbalance and overcommitment in reference to employees' self-reported health in a large sample of employees in a highly competitive industry. We used a number of selected outcome measures (vital exhaustion, health-related quality of life, depression, and sleep), some of which have been implicated as risk factors for cardiovascular disease (Rozanski, Blumenthal, & Kaplan, 1999). While numerous studies demonstrated effort-reward imbalance to be of importance for employees' health (Siegrist, 2002b), there are just a few studies linking overcommitment or its interaction with effort-reward imbalance to poorer health (Godin & Kittel, 2004; Joksimovic, Starke, v d Knesebeck et al., 2002; Niedhammer, Tek, Starke et al., 2004; Tsutsumi, Kayaba, Theorell et al., 2001).

The main findings are that employees reporting a mismatch between their efforts and occupational rewards showed lower health-related quality of life, a pronounced risk of sleeping problems, vital exhaustion, and depressed mood, compared to people reporting no high costs/low gain conditions. These findings corroborate earlier results identifying high effort-reward-imbalance status at work as a risk constellation for employees' health and well-being (de Jonge, Bosma, Peter et al., 2000; Godin & Kittel, 2004; Joksimovic, Starke, v d Knesebeck et al., 2002; Niedhammer, Tek, Starke et al., 2004; Pikhart, Bobak, Pajak et al., 2004; Siegrist, 2002b; Stansfeld, Bosma, Hemingway et al., 1998; Tsutsumi, Kayaba, Theorell et al., 2001). Our results extend these findings in two respects: (a) high overcommitment has an impact on health indicators similar to that of effort-reward imbalance, in same the direction and to the same extent (standardized beta coefficients ranged from |0.22| (SF12 mental health) to |0.49| (vital exhaustion)), and (b) in addition to the theoretical assumption of the ERI model, where it was postulated that the ratio of effort to reward is what matters most (Siegrist, 2002), overcommitment appears to operate as a relevant component in explaining different health outcomes. Most important, our findings support the notion that the strongest effects on health and well-being are likely to occur if both structural (i.e., effort-reward imbalance) and personal components (i.e., overcommitment) are operating simultaneously. Individuals with high overcommitment and effort-reward imbalance reported the strongest deviations in the scales used in this study (standardized beta coefficients ranged from |0.46| (SF12 physical health) to |1.14| (vital exhaustion)), as compared to the reference group. In keeping with the theoretical assumption, this finding supports the assumption that highly overcommitted people were unable to accurately assess cost-gain relations and to withdraw from work obligations for recovery (Siegrist, 1996). In other words, our data suggest that the interaction between overcommitment and effort-reward imbalance constitutes the most important 'toxic' combination for maintaining self-reported health and well-being. From a theoretical view, it is the interplay of both personal and structural components that 'matters most'.

Several potential caveats of the present study have to be addressed. First, one major limitation can be seen in the fact that both explanatory and outcome variables are based on self-report data. Self-report measures have often been criticized because the interpretation of observed relations is always somewhat ambiguous, e.g., (Kasl, 1998; Kristensen, 1996). It is possible that broader constructs, like negative affectivity, may contaminate the correlation between the dependent and independent variables. Negative affectivity has been shown to account for some of the variance in self-report measurements in several variables, including assessments of job strain and health complaints, e.g., (Brief, Burke, George, Robinson, & Webster, 1988; Vassend, 1989; Watson & Pennebaker, 1989). There is an ongoing debate on the question of whether negative affectivity should be taken into account in occupational stress research (Brief, Burke, George et al., 1988). Others suggest controlling for negative affectivity in studies based on self-reports of psychosocial working conditions (Spector, Zapf, Chen, & Frese, 2000). Our data suggest that the effects hold regardless of whether controlled for negative affectivity or not. A second, serious limitation concerns the cross-sectional design of our study that does not permit causal inferences between the ERI components and self-rated health dimensions (Zapf, Dormann, & Frese, 1996). Most important, however, is the fact that our data may underestimate the true extent of the effects. Our study population experienced relatively high job security provided both by the company and German workplace legislation, unrestricted access to health care and even the group of skilled workers represented the upper portion of their peer group regarding socioeconomic status. Thus our population was lacking the extremes with respect to working conditions and socioeconomic status that exist in the general population.

One major strength of this study is that the original measures of effort-reward imbalance and overcommitment were used, so crude proxy measures were avoided. A further strength of the study can be seen in the comprehensive assessment of self-reported health in a large sample of employees, including well-established measures of exhaustion, quality of life, sleep and depressed mood. In this sample the participants had, on average, been with the company for about 10 years. Many of them had not changed their workplace for a decade or more. Hence, the descriptions of work characteristics may represent a trait beyond the usual recall period of questionnaire data.

Our findings ultimately relate to health prevention at the workplace. More precisely, the critical combination between high imbalance and high overcommitment should serve as a starting point for intervention strategies to maintain employees' well-being and self-reported health. Employees who are susceptible to poorer health than others because they commit themselves in a too exhaustive manner to work demands might profit from cognitive-behavioral therapy at an early stage of perceived job strain. Preventive interventions might help individuals to adopt more favorable coping patterns when exposed to stressful work circumstances, as well as to reflect on the ideas and assumptions driving their overcommitment. Employees' perception of an imbalance between efforts and rewards could be changed by means of occupational and organizational psychology interventions. Our data suggest that human resource management should be particularly aware of signs heralding health symptoms in their overcommitted and high-imbalance staff, because otherwise exhaustion may exacerbate into burnout syndrome.

Summarizing our findings, the present study demonstrated that the interaction between effort-reward imbalance and overcommitment is related to poorer self-reported health in terms of vital exhaustion, sleep problems, mental health, and depressed mood. The results support the prognostic validity of the ERI model, indicating not only the impact of organizational fairness, e.g. the absence of effort-reward imbalance, but also the importance of personal coping.

5.3 Study III: Effort-reward-imbalance/overcommitment – their relation to allostatic load

ABSTRACT

Background: Imbalance between work-related effort and reward has emerged as an independent psychosocial risk factor for cardiovascular disease. The effort-reward-imbalance (ERI) model postulates that this imbalance is aggravated by the adverse personal coping style overcommitment (OC). We aimed at elucidating the association of ERI-OC with physiological indicators of the metabolic syndrome and of allostatic load.

Methods: Participants were healthy employees (mean age 39.1 ± 11.7 years; 87 % male) from the airplane manufacturing industry in Southern Germany. We divided the population into high (upper quartile) and low subgroups across each scale into four groups: low ERI / low OC (reference, 58.7%), low ERI / high OC (11.8%), high ERI / low OC (15.9%) and high ERI / high OC (the most adverse condition, 13.6%). Dependent variables were: body mass index, waist-hip ratio, systolic and diastolic blood pressure, white blood cell counts, glycosylated hemoglobin, HDL and LDL, C-reactive protein, fibrinogen, D-dimer, dehydroepiandrosterone sulfate; urinary excretion of albumin, cortisol, epinephrine and norepinephrine.

Results: For 1553 subjects data on all psychometric scales including ERI/OC were available, of these 1039 individuals had complete datasets including socio-demographic information, health behavior variables and non-missing / non-pathological values for all biological parameters. Adjusted analysis controlling for age, gender, alcohol intake, smoking, and physical activity revealed that subjects reporting high ERI and high overcommitment had significantly higher waist to hip ratio (+0.02), diastolic blood pressure (+1.54 mm Hg), LDL-cholesterol (+6.56 mg/dl), white blood cell count (+0.38 x 10^9 cells/l), C-reactive protein (+0.05 mg/dl), urinary albumin excretion (+0.17 mg/l), and overnight epinephrine excretion (+0.15 mmol/g creatinin) as compared to the reference-group.

Conclusion: ERI imbalance and high overcommitment are associated with higher levels of several biological variables. While associations with individual biomarkers are of questionable clinical relevance, the cumulative burden suggests increased risk of metabolic syndrome and of allostatic load.

Keywords: Effort-reward-imbalance, overcommitment, risk factors, allostatic load

INTRODUCTION

Chronic stress at work has been implicated as a psychosocial risk factor for cardiovascular disease (Hemingway & Marmot, 1999; Rozanski, Blumenthal, & Kaplan, 1999; Krantz & McCeney, 2002). The impact of chronic work stress on physical health has been conceptualized with different theoretical models (Karasek & Theorell, 1990; Levi, Bartley, Marmot, Karasek, Theorell, Siegrist et al., 2000; Semmer & Mohr, 2001; Siegrist, 2002). Several longitudinal studies have identified Effort-Reward-Imbalance (ERI) as an independent risk factor for adverse cardiovascular outcomes (Bosma, Peter, Siegrist, & Marmot, 1998; Kivimaki, Leino-Arjas, Luukkonen, Riihimaki, Vahtera, & Kirjonen, 2002; Kuper, Singh-Manoux, Siegrist, & Marmot, 2002). Studies also related ERI to adverse psychological outcomes such as depression (Tsutsumi, Kayaba, Theorell, & Siegrist, 2001) and to health related quality of life (Stansfeld, Bosma, Hemingway, & Marmot, 1998). The ERI model assumes that a failed reciprocity between efforts and rewards (“effort-reward-imbalance”) may adversely affect the stress regulatory mechanisms, which in turn trigger subsequent secondary biological alterations involved in the pathogenesis of a variety of adverse health outcomes including coronary heart disease (Siegrist, 1996; Siegrist, 2001, 2002). An important amendment to the model is the postulate that an individual's exhaustive coping style, known as overcommitment may aggravate the negative consequences of effort-reward-imbalance for health. The overcommitment model postulates that excessive striving for approval and appreciation may lead to irritability and the individual’s inability to withdraw from work obligations during leisure time. Thus, the full ERI-overcommitment model explicitly distinguishes between a situational component describing job conditions, and a personal component.

To date, little is understood about the biological mechanisms mediating the association between this psychosocial risk factor and cardiovascular disease (Siegrist, 1996). Moreover, the affect of the interaction between overcommitment and effort-reward-imbalance on physiological measures has rarely been studied. Identified biological variables possibly mediating the long-term adverse effects of effort-reward-imbalance include elevated blood pressure (Peter, Alfredsson, Hammar, Siegrist, Theorell, & Westerholm, 1998; Peter & Siegrist, 1997; Steptoe, Siegrist, Kirschbaum, & Marmot, 2004), artherogenetic lipids (Peter, Alfredsson, Hammar et al., 1998), impaired fibrinolysis (a decrease in t-PA activity and an increase in PAI-1 activity) (Vrijkotte, van Doornen, & de Geus, 1999; Siegrist, Peter, Cremer, & Seidel, 1997) and elevated morning cortisol (Steptoe, Siegrist, Kirschbaum et al., 2004). In a recent study on Japanese workers exhibiting symptoms of distress following reorganization, effort-reward-imbalance was associated with increased hematocrit, liver transaminases, and decreased serum levels of high density lipoprotein (HDL) (Irie, Tsutsumi, Shioji, & Kobayashi, 2004). Generally, the observed effect sizes are small, but of potential clinical relevance.

A framework to conceptualize the biological link from behavioral or psychosocial stressors to adverse health outcomes is the allostatic load model (McEwen, 1998). According to the model, the organism reacts to external or internal stressors with an adaptive physiological reaction named allostasis. The allostatic response requires alterations in primary mediators by the vegetative nervous system and by the endocrine hormone systems, which in turn lead to secondary changes in physiological parameters such as blood pressure and plasma lipid concentrations of serum glucose levels. Excessive (e.g. frequent and persistent) demands on allostatic adaptation to stressors lead to dysregulation in multiple physiological systems (Karlamangla, Singer, McEwen, Rowe, & Seeman, 2002). This cost of wear and tear to the body as a consequence of excessive allostatic adaptation is termed allostatic load. Allostatic load has been conceptualized in several cumulative measures, which aim to reveal variations in the sequential nature of primary, secondary, and tertiary changes throughout the various physiological systems. In the MacArthur studies on successful aging a 10-parameter operationalization of an allostatic load score predicted subsequent 7-year mortality, cardiovascular events, and mental decline (Seeman, McEwen, Rowe, & Singer, 2001). The MacArthur study investigators (Seeman, McEwen, Rowe et al., 2001) suggested augmenting the original panel by including indicators of immune functioning, inflammation, and haemostasis. There is considerable measurement overlap between allostatic load and the metabolic syndrome, since a subset of the variables employed to calculate allostatic load scores are used to define the metabolic syndrome.

In the present cross-sectional study we employed the original allostatic load comprising systolic and diastolic blood pressure, waist-hip ratio, plasma levels of cholesterol, high-density lipoprotein (HDL), and dehydroepiandrosteron sulphate (DHEA-S); blood levels of glycosylated haemoglobin (Hb1Ac), and urinary secretion of cortisol, epinephrine, and norepinephrine (Seeman, McEwen, Singer, Albert, & Rowe, 1997). This panel was extended by plasma levels of high-sensitivity C-reactive protein (CRP) (Blake, Rifai, Buring, & Ridker, 2003; Folsom, Pankow, Tracy, Arnett, Peacock, Hong et al., 2001; Koenig, 2003b), micro-albuminuria as an indicator of subclinical renal impairment (Mimran & Ribstein, 1996), body-mass-index to reflect adverse nutritional intake (Hecker, Kris-Etherton, Zhao, Coval, & St Jeor, 1999; Skurk & Hauner, 2004; Lakka, Lakka, Salonen, Kaplan, & Salonen, 2001), and plasma levels of D-dimer (Danesh, Whincup, Walker, Lennon, Thomson, Appleby et al., 2001) and fibrinogen (Koenig, 2003a) as indicators of a procoagulant profile.

We have previously reported a week association between job strain and allostatic load, in particular elevated levels of C-reactive protein. Here we apply the full effort reward-imbalance model including the overcommitment component to a much larger cohort of individuals from the same population (Schnorpfeil, Noll, Schulze, Ehlert, Frey, & Fischer, 2003). We hypothesized that particularly the combination of high effort-reward-imbalance and high overcommitment would be associated with an increase of indices of the metabolic syndrome and allostatic load.

METHODS

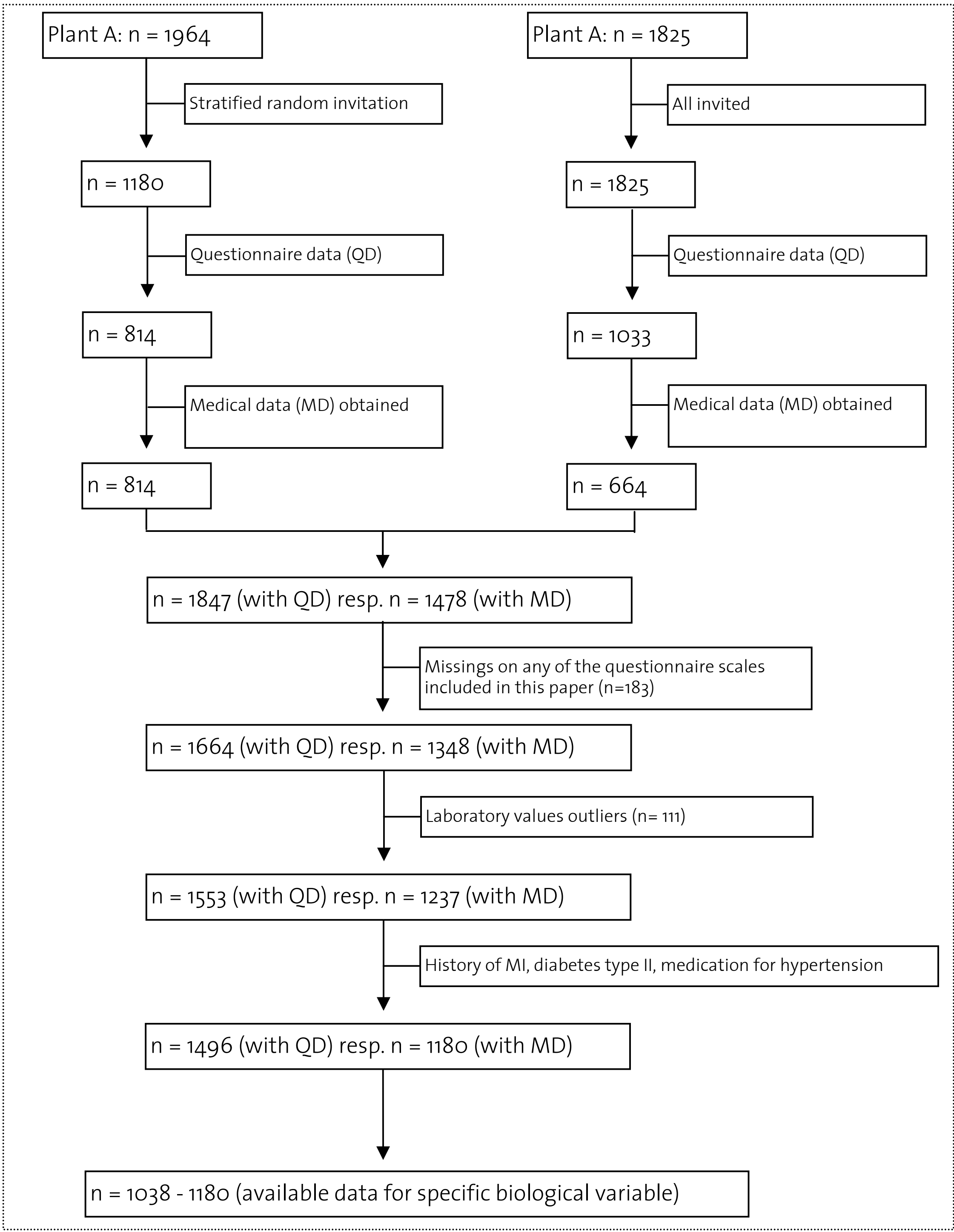
Participants

Participants were recruited in two successive enrolment periods to the ETH-cohort project from two separate production plants of the EADS airplane manufacturing industry in Southern Germany. For the first study site, the recruitment procedure followed a stratified sampling strategy initially selecting 1150 employees as potential study participants, of whom 814 consented. At the second study site, all permanent employees (n = 1825) were eligible to partake in the study, of whom 1033 completed questionnaires and 664 partook in the medical examination. Figure 1 displays the recruitment and drop-out numbers. In both study sites, time for participation was recorded as working time. No further incentives were offered, except for an individualized feedback and data summary sheet. The studies were approved by the Institutional Review Board. All participants provided written informed consent.

The highly qualified airplane manufacturing employees reflect the upper qualification range of blue collar workers. During the period of data collection, the two plants experienced relatively stable macro-economic conditions. All participants had free access to health care and were covered by the comprehensive German social security system. Thus, extremes of adverse working conditions as well as excessive job insecurity were not prevalent in this sample.

From the present analysis we excluded subjects with a positive history of coronary heart disease, or diabetes type I / diabetes type II. We also excluded subjects with biological values differing more than four standard deviations from the study population mean, and subjects with missing data on effort-reward-imbalance and overcommitment scale (Figure).

Figure: Data collection



Study design

During a one-hour group session (10 – 25 individuals), each participant completed a set of questionnaires after a standardized oral introduction. Group sessions were held in a room isolated from the working environment. All participants from the questionnaire assessment were offered subsequent medical examination. Volunteers were required to complete an extensive medical questionnaire, to undergo a basic physical examination, to collect urine during the night between two working days, and to present the next morning prior to commencing work within two hours of awakening for collection of overnight fasting blood samples. Further descriptions of the study procedures have been previously reported (von Kanel, Maly, Frey, & Fischer, 2003). Where applicable, we replicated the data collection procedures employed in our earlier study (Schnorpfeil, Noll, Schulze et al., 2003).

Data collection

Questionnaire data

Effort-reward-imbalance was measured using the revised scales of the ERI model recently published by Siegrist and co-workers (Siegrist, 2002). Effort is measured by 6 items that refer to demanding aspects of the work environment. Reward is measured by 11 items reflecting the subscales monetary reward, esteem, and job security. The questions are worded to specifically assess the personal level of distress experienced by each effort and reward item, respectively. The ratio of effort and reward (denominator) expresses the amount of effort-reward-imbalance. The resulting ratio score implies that individuals with a ratio larger than 1 experience severe effort-reward-imbalance (Peter, Alfredsson, Hammar et al., 1998). In the present study, the internal reliability for effort (Cronbach's α) was 0.72, for reward 0.85.

Overcommitment was assessed with the 6-item short form of the intrinsic effort scale (“immersion”) of the effort-reward model (Niedhammer, Tek, Starke, & Siegrist, 2004; Siegrist, 2002). The short form focuses on the “inability to withdraw from work” (5 items) and “disproportionate irritability” (1 item). Cronbach's α for the overcommitment score was 0.81. Additional data obtained by the questionnaire included the medical history and health-related behavior (cigarette smoking, physical exercise, medication), other work characteristics and personality traits (Schnorpfeil, Noll, Schulze et al., 2003; Kudielka, von Kanel, Gander, & Fischer, 2004). These variables served to control for potential confounding as explained in detail below.

Biological measurements

Biological measurements included the following indicators for the metabolic syndrome or allostatic load (Seeman, McEwen, Rowe et al., 2001): systolic and diastolic blood pressure (SBP and DBP, as indices of cardiovascular activity); waist-to-hip ratio (WHR) (an index of central obesity); serum high density lipoprotein (HDL), low density lipoprotein (LDL) and total cholesterol (risk for atherosclerosis with higher levels of total cholesterol and lower levels of HDL) (Pocock, McCormack, Gueyffier, Boutitie, Fagard, & Boissel, 2001; Spieker, Ruschitzka, Luscher, & Noll, 2004; Packard, Nunn, & Hobbs, 2002); blood plasma levels of glycosylated haemoglobin (HbA1c); overnight urinary excretion of cortisol (an integrated indicator of the HPA axis activity) as well as norepinephrine and epinephrine (integrated measure of the sympathetic nervous system activity). Urinary concentrations were adjusted for the amount of excreted creatinine.

In addition to these measures employed by Seeman and co-workers, we followed their suggestion to extend the allostatic load panel by including indicators of inflammatory activity and haemostasis function (Seeman, McEwen, Rowe et al., 2001). Specifically, we assed inflammatory activity by determination of plasma levels of C-reactive protein (CRP) using a high sensitivity assay. CRP has been implicated as an independent risk factor for cardiovascular disease (Hak, Stehouwer, Bots, Polderman, Schalkwijk, Westendorp et al., 1999; Blake & Ridker, 2001). The total white blood cell count was included as a readily available independent predictor of future cardiovascular events. Numerous epidemiologic and clinical studies have identified leukocytosis as an independent risk factor with a consistent, temporal, and dose-dependent relation to cardiovascular disease (Madjid, Awan, Willerson, & Casscells, 2004). The body mass index served to estimate chronic excess of nutritional intake (Hecker, Kris-Etherton, Zhao et al., 1999; Lakka, Lakka, Salonen et al., 2001). Haemostatic functioning was determined from plasma levels of D-Dimer and fibrinogen (Danesh, Whincup, Walker et al., 2001; Koenig, 2003a).

Biological data were obtained as follows: blood pressure readings were computed as the average of two seated readings after a minimum of 15 min. rest period in sitting position. Waist-to-hip ratio was calculated based on waist circumference (measured at the narrowest point between the ribs and iliac crest) and hip circumference (measured at the maximal buttocks). Fasting blood collection was scheduled for the second of two working days approximately two hours after awakening in order to minimize circadian effects. Blood samples were processed within six hours from collection in a commercial laboratory (Synlab, Augsburg, Germany) using laboratory standard procedures. Further details have been reported elsewhere (Schnorpfeil, Noll, Schulze et al., 2003; von Kanel, Maly, Frey et al., 2003).

Statistical Analysis

In order to evaluate the interaction between effort-reward-imbalance and overcommitment, we divided the study population into high and low subgroups across each scale: low ERI / low OC (reference, 58.7%), low ERI / high OC (11.8%), high ERI / low OC (15.9%) and high ERI / high OC (the most adverse condition, 13.6%). Regarding effort-reward-imbalance, we employed the suggested cut-off of 1, with ratios > 1 indicating serious effort-reward-imbalance (Siegrist, 2002). Regarding overcommitment, we employed an empirical cut-off of 16 (scale range 6-24), which comprises the highest quartile of the distribution in the present sample. The four subgroups were coded as dummy variables. The following biological non-normally distributed measures were log-transformed for group comparisons: CRP, urinary albumin, urinary norepinephrine and epinephrine. We report the mean and 95% confidence intervals for the mean. Groups were compared using analysis of variance.

To estimate the non-normality of some indicator variables, we confirmed the results by the non-parametric Kruskal-Wallis-test for unadjusted comparisons. In a second step, we regressed each allostatic load indicator variable on the four dummy variables, controlling for age, gender, alcohol consumption, smoking, and physical activity. Alcohol consumption was dummy-coded as the median split across the self reported regular alcohol intake (> 16 g/day). Smoking was dummy-coded as smoker vs. non-smoker. Abnormal laboratory values led to the exclusion of 111 individuals (predominantly excluded for probable active inflammation, n = 14; excessive values for D-dimer, n = 21; very high urinary cortisol excretion, n = 21; and albuminuria n = 31). Further 57 individuals were excluded for history of myocardial infarction or treated diabetes type II. We repeated all analyses using less stringent exclusion criteria. The results did not substantially differ from those reported here. Because we aimed at elucidating the association between adverse psychosocial working conditions and biological measures in apparently healthy individuals, we regard the presented results as those most appropriate to our research question. Analyses were carried out using SAS (version 8.2, SAS Institute, Cary, NC, USA). A type-I error probability of less than .05 indicated statistical significance. All analyses were controlled for age, gender, alcohol, smoking, and physical activity.

RESULTS

The present analysis included 1553 employees with valid (non-missing) data on effort-reward-imbalance and overcommitment. Mean age was 39.1 ± 11.7 years (age range 16 – 63 years). The majority of participants was male and qualified skilled workers (Table 1). Every second employee (n=1039; 65.5%) had worked in the company for more than 10 years. The distribution of effort-reward-imbalance and overcommitment differed significantly across job positions ($p<0.001$; Table 1). Compared to the skilled workers, foremen and senior managers more often reported low imbalance with high overcommitment or high imbalance with low overcommitment. Almost all trainees (94.1%) experienced low overcommitment and low effort-reward-imbalance. Regarding the total sample, the reference group with low overcommitment and low imbalance comprised 58.7% of the participants.

Table 1: Sample characteristics

	Total (%)*	Low imbalance		High imbalance	
		Low OC (%)	High OC (%)	Low OC (%)	High OC (%)
Gender					
Male	1381 (87.0%)	815 (59.0%)	158 (11.5%)	227 (16.4%)	181 (13.1%)
Female	207 (13.0%)	117 (56.5%)	29 (14.0%)	26 (12.6%)	35 (16.9%)
Total (valid)	1588 (100%)	932 (58.7%)	187 (11.8%)	253 (15.9%)	216 (13.6%)
Position					
Senior manager	69 (4.4%)	39 (56.5%)	11 (15.9%)	15 (21.7%)	4 (5.8%)
Foremen	192 (12.1%)	85 (44.3%)	39 (20.3%)	49 (25.5%)	19 (9.9%)
Qualified workers	1174 (73.9%)	695 (59.2%)	150 (12.8%)	118 (10.1%)	211 (18.0%)
Unskilled workers	45 (2.8%)	15 (33.3%)	14 (31.1%)	3 (6.7%)	13 (28.9%)
Trainees	102 (6.4%)	96 (94.1%)	0 (0.0%)	2 (2.0%)	4 (3.9%)
Missing	6 (0.4%)	2 (33.3%)	2 (33.3%)	0 (0.0 %)	2 (33.3%)
Age (years)	39.1 (± 11.7)	37.3 (± 12.2)	42.3 (± 10.8)	39.5 (± 10.4)	43.7 (± 9.8)
Smoking					
Smoker (yes)	1000 (63.0%)	579 (57.9%)	135 (13.5%)	148 (14.8%)	138 (13.8%)
Smoker (no)	546 (34.4%)	331 (60.6%)	49 (9.0%)	91 (16.7%)	93 (13.7%)
Missing	42 (2.6%)	22 (52.5%)	3 (7.1%)	14 (33.3%)	3 (7.1%)
Self reported alcohol intake					
Above median	593 (37.3%)	361 (60.9%)	66 (11.1%)	84 (14.2%)	82 (13.8%)
Below median	925 (58.2%)	537 (58.1%)	115 (12.4%)	148 (16.0%)	925 (13.5%)
Missing	70 (4.4%)	34 (48.6%)	6 (8.6%)	21 (30.0%)	9 (12.8%)

Notes: * For the total sample the percentage relates to the column, e.g. n=1381 of n=1588. For the four subgroups, percentage relates to the respect row, e.g. 59% of n=1381.

Biological indicators

Unadjusted analysis across the four groups revealed significant differences for several indicators (Table 2). Individuals experiencing severe effort-reward-imbalance regardless of their overcommitment score had higher systolic and diastolic blood pressure, increased waist-to-hip ratio, a higher body mass index, as well as higher cholesterol and LDL levels. They also had higher numbers of circulating leukocytes, lower levels of DHEA-S and secreted significantly larger quantities of norepinephrine. In the high imbalance – high overcommitment group, the highest values were observed for systolic blood pressure, BMI, cholesterol, LDL, and white blood cell count. The crude differences across groups amounted to about 10 percent higher values for white blood cell count or LDL in the high imbalance – high overcommitment group, and to about a 10 percent decline in DHEA-S levels, respectively.

Table 2: Means, 95% confidence intervals, and results of ANOVA stratified by high vs. low ERI and OC groups

			Low ERI		High ERI		Anova
	N	Mean (SD)	Low OC (SEM)	High OC (SEM)	Low OC (SEM)	High OC(SEM)	p
Physical examination							
Body mass index (kg/m²)	1160	26.2 (24.88 - 27.52)	26.0 (24.65 - 27.35)	26.1 (24.85 - 27.35)	26.2 (24.92 - 27.48)	27.0 (25.72 - 28.28)	**0.02**
Waist-hip ratio	1158	0.92 (0.90 - 0.94)	0.92 (0.9 - 0.94)	0.92 (0.9 - 0.94)	0.94 (0.92 - 0.96)	**0.94 (0.92 - 0.96)**	**<0.001**
Systolic BP (mm Hg)	1160	125.8 (120.24 - 131.36)	125 (119.65 - 130.35)	123.9 (117.84 - 129.96)	127.3 (122.2 - 132.4)	128.6 (122.4 - 134.8)	**0.06**
Diastolic BP (mm Hg)	1160	80.8 (77.31 - 84.29)	80.0 (76.54 - 83.46)	81.2 (77.56 - 84.84)	81.5 (78.26 - 84.74)	82.7 (78.96 - 86.44)	**0.04**
Blood measurements							
Leukocytes	1147	6.2 (5.59 - 6.81)	6.09 (5.52 - 6.66)	5.91 (5.25 - 6.57)	6.38 (5.84 - 6.92)	**6.61 (5.88 - 7.34)**	**<0.001**
HbA1c	1148	5.3 (5.13 - 5.47)	5.28 (5.12 - 5.44)	5.29 (5.12 - 5.46)	5.32 (5.14 - 5.5)	5.35 (5.15 - 5.55)	0.34
Cholesterol (mg/dl)	1147	213.7 (198.15 - 229.25)	210.9 (194.93 - 226.87)	213.8 (199.68 - 227.92)	212.5 (197.52 - 227.48)	**224.7 (209.58 - 239.82)**	**0.01**
HDL	1147	54.5 (49.94 - 59.06)	54.5 (49.83 - 59.17)	54.6 (49.96 - 59.24)	54 (49.72 - 58.28)	55.2 (50.67 - 59.73)	0.78
LDL	1147	136.7 (123.61 - 149.79)	133.5 (120.06 - 146.94)	136.1 (123.66 - 148.54)	139 (126.98 - 151.02)	**146 (133.02 - 158.98)**	**<0.001**
Total Chol / HDL ratio	1146	4.11 (3.68 - 4.54)	4.06 (3.63 - 4.49)	4.13 (3.67 - 4.59)	4.1 (3.71 - 4.49)	4.26 (3.83 - 4.69)	0.26
CRP	1114	0.18 (0.1 - 0.26)	0.18 (0.09 - 0.27)	0.16 (0.08 - 0.24)	0.17 (0.1 - 0.24)	0.2 (0.11 - 0.29)	0.26
Fibrinogen	1141	274.2 (252.61 - 295.79)	275.3 (253.53 - 297.07)	285.6 (262.47 - 308.73)	265.4 (245.24 - 285.56)	271.3 (250.46 - 292.14)	0.16
D-dimer	1133	141.9 (113.96 - 169.84)	143.6 (116.05 - 171.15)	151.7 (122.68 - 180.72)	133.3 (105.64 - 160.96)	137.6 (109.05 - 166.15)	0.12
DHEA-S	1142	2.62 (2.18 - 3.06)	2.65 (2.21 - 3.09)	2.56 (2.1 - 3.02)	2.78 (2.32 - 3.24)	**2.35 (1.97 - 2.73)**	**0.03**
Urinary excretion							
Albumin	1038	5.64 (3.99 - 7.29)	5.46 (3.84 - 7.08)	5.5 (3.69 - 7.31)	6.22 (4.57 - 7.87)	5.8 (4.24 - 7.36)	0.20
Urinary cortisol (µg/l)	1141	51.2 (41.23 - 61.17)	51.7 (41.69 - 61.71)	52.9 (43 - 62.8)	49 (39.49 - 58.51)	50.6 (40.31 - 60.89)	0.52
Cortisol/Creatinine	1142	41.9 (34.75 - 49.05)	41.8 (34.62 - 48.98)	43.3 (36.83 - 49.77)	40.1 (32.7 - 47.5)	43.3 (36.08 - 50.52)	0.34
Norepinephrine/Creatinine	1142	20.8 (17.15 - 24.45)	19.5 (16.25 - 22.75)	20.4 (16.58 - 24.22)	24.1 (20.17 - 28.03)	22.1 (18.03 - 26.17)	**<0.001**
Epinephrine	1135	3.04 (2.16 - 3.92)	2.97 (2.02 - 3.92)	3.04 (2.15 - 3.93)	3.26 (2.58 - 3.94)	3.06 (2.27 - 3.85)	0.51

Notes: All results were confirmed using non-parametric tests. CRP, albumin, norepinephrine and epinephrine values are provided as the geometric mean. Urinary concentrations are expressed as µg per g creatinine or as mg per g creatine (albumin).

In a subsequent multivariable regression analysis we controlled for potential confounding by age, gender, alcohol intake, smoking, and physical activity. The resulting beta-coefficients are presented in Table 3. Supporting the findings from the crude analysis, and compared to the low overcommitment – low effort-reward-imbalance group, higher values were found in one or more of the other groups for diastolic blood pressure, waist-to-hip ratio, LDL, white blood cell count, CRP, and urinary excretion of albumin and catecholamines. Significantly lower values were found for fibrinogen. The columns to the right side of Table 3 show the corresponding standardized beta-coefficients for significant confounders. This allows comparing effect sizes of the ERI / overcommitment model to known behavioral or demographic risk factors. Our analysis suggests that the increase in the effect size of waist-to-hip ratio and CRP-values attributable to the combination of high imbalance and high overcommitment is similar in magnitude to the increase attributable to one additional decade of biological age. The differences in LDL were about as large as the differences observed between high versus low alcohol intake. The effect for the white blood cell count was about as large as the gender difference.

Table 3: Beta-Coefficients of low vs. high ERI and OC groups controlled for relevant confounders

	Low ERI		High ERI		Confounders[3]				
	Low OC[1]	High OC	Low OC	High OC	Age (Decade)	Gender[2]	Alcohol	Smoking	R^2
Physical examination									
BMI (kg/m²)	**24.69**	-0.268	0.164	0.512	**0.97*****	**1.60*****	0.007	0.137	0.13
Waist-hip ratio	**0.84**	0.000	**0.017*****	**0.018*****	**0.02*****	**0.096*****	0.003	**0.01****	0.39
Systolic BP (mm Hg)	**117.1**	-1.77	1.78	1.495	**3.60*****	**7.56*****	**1.96***	1.718	0.13
Diastolic BP (mm Hg)	**76.05**	0.305	1.106	**1.54***	**2.80*****	**3.80*****	0.98	0.165	0.16
Blood measurements									
Leukocytes	**6.02**	-0.144	0.179	**0.379****	**0.14*****	**-0.452****	-0.165	**1.48*****	0.15
HbA1c	**5.13**	-0.048	0.027	-0.014	**0.10*****	-0.05	-0.046	**0.14*****	0.10
Cholesterol (mg/dl)	**175.4**	-3.24	0.25	6.09	**15.7*****	3.12	**11.64*****	2.88	0.21
HDL	**65.60**	-0.25	-0.033	-0.114	0.435	**-12.9*****	**3.91*****	**-3.33*****	0.14
LDL	**122.5**	-2.22	3.67	**6.56***	**12.4*****	**10.7*****	**6.65****	4.19	0.19
Total Chol / HDL ratio	**3.28**	-0.042	-0.031	0.094	**0.29*****	**0.855*****	-0.09	**0.30*****	0.15
CRP	**-2.07**	-0.15	0.03	**0.176***	**0.14*****	**-0.474*****	-0.024	0.346	0.06
Fibrinogen	**294.1**	4.03	**-11.0***	**-12.5***	**13.3*****	**-24.0*****	**-9.76****	**15.3*****	0.09
D-dimer	**172.1**	10.93	-4.19	-0.09	**-7.70*****	**-35.1*****	4.11	-6.46	0.04
DHEA-S	**0.99**	0.15	0.164	-0.023	**-0.75*****	**0.983*****	**0.198****	**0.273*****	0.34
Urinary excretion									
Albumin	**1.27**	0.03	**0.222****	**0.167***	**-0.09*****	0.08	-0.04	**0.146****	0.02
Cortisol/creatinine	**49.79**	-0.39	-1.98	-0.10	**3.20*****	**-8.04*****	0.90	-2.26	0.05
Norepinephrine	**10.55**	0.065	**0.222*****	0.047	**1.96****	**0.196****	-0.05	**0.223*****	0.05
Epinephrine	**0.44**	0.093	**0.240*****	**0.159***	**-0.06****	**0.387*****	**-0.10***	**0.015****	0.06

Notes: [1]Reference group in dummy regression analysis (Intercepts) [2]Reference is gender = female [3]Data for 'physical activity' were not significant (excepted for HbA1c: Beta coefficient was 0.03) and are not shown $^{***}p<0.001$ $^{**}p<0.01$ $^{*}p<0.05$. 'Age' is equivalent to a period of 10 years. All coefficients were centred to a 40 year old, female employee. Smoking was classified as smoker vs. non-smoker, alcohol as above vs. below the median split of self reported intake.

DISCUSSION

In this cross-sectional study of 1553 employees of the German airplane manufacturing industry, we investigated the possible association of adverse working conditions with physiological indicators of allostatic load and the metabolic syndrome. Allostatic load is a construct pertaining to the cumulative wear and tear on the organism as a consequence of repetitive and chronic adaptation to environmental or behavioral stressors encountered by the individual. For the present study we assessed adverse working conditions using the effort-reward-imbalance / overcommitment model. This model emphasizes work related violations of social reciprocity and the effect of a personal coping style that fails to counteract reduced reciprocity. The main finding of our study is that high imbalance combined with high overcommitment is associated with significantly increased waist to hip ratio, diastolic blood pressure, LDL cholesterol, leukocytes, CRP, albumin, and epinephrine compared to a reference-group reporting low imbalance and low overcommitment after controlling for age, gender, alcohol intake, physical exercise, and smoking. These results suggest that the constellation of high effort-reward-imbalance and high overcommitment may be associated with sustained sympathetic nervous system activation as evidenced by increased diurnal catecholamine secretion, and increased inflammation, indicated by higher plasma levels of C-reactive protein and higher white blood cell counts. In contrast to previous studies (Siegrist, Peter, Cremer et al., 1997), we found a decrease in fibrinogen-levels under high imbalance conditions when controlling for possible confounding. Under conditions of reciprocity (no imbalance), overcommitment showed no impact on allostatic indices or metabolic syndrome. However, it appeared to aggravate the changes observed with high imbalance alone.

Our data lend specific support to the accumulating evidence that chronic job stress is accompanied by profound changes across many biological systems such as the cardiovascular system, and the inflammatory system (Belkic, Schnall, Landsbergis, & Baker, 2000). While our data corroborate previous findings that job stress is associated with increased diastolic blood pressure (Peter, Alfredsson, Hammar et al., 1998; Peter & Siegrist, 1997; Vrijkotte, van Doornen, & de Geus, 2000), the present study fails to replicate earlier findings of elevated fibrinogen levels in subjects with effort-reward imbalance (Vrijkotte, van Doornen, & de Geus, 1999). As has previously been shown for job strain, we found increased LDL cholesterol levels associated with adverse effort-reward-imbalance and overcommitment. In contrast to previous studies, we had purposely selected the array of biological measurement to reflect the concept of allostatic load as applied in the MacArthur studies of successful aging (Seeman, McEwen, Rowe et al., 2001; Fischer, 2003). Our data lend support to the notion of a knock-on-effect of changes that begin in primary mediators (e.g. catecholamines), which in turn alter secondary physiological functions such as LDL or diastolic blood pressure. In contrast to the MacArthur studies, we chose the allostatic load index as the dependent variable and not as a predictor of future health outcomes. Moreover, our sample comprised the entire life-span of working populations. Hence, the applied adjustment for the prominent age effect was mandatory.

The present study underscores the importance of health prevention at the workplace. The interaction between high effort-reward-imbalance and high overcommitment appears to affect a variety of physiological functions that are commonly perceived as predominantly related to personal health behavior and genetic make-up. Physicians treating working individuals should bear in mind that a potentially relevant proportion of physiological aberrations may reflect an individual's biological response to adverse working conditions, independently of altered health behavior. To this end, a state of high imbalance and high overcommitment might be a particularly "toxic" combination. A very simplistic summary of our findings would be that the cumulative changes observed in the most adverse effort-reward imbalance / overcommitment group correspond to the cumulative effect of about a half to one decade of age.

Our study of more than 1000 healthy adult employees extends previous investigations by applying McEwens allostatic load concept for the first time to test the predictive validity of Siegrist's Effort-Reward-Imbalance model. Although the strength of this study can be seen in the comprehensive measurement of allostatic load, incorporating a broad spectrum of biological markers of future disease, we must acknowledge several limitations of the study design. A serious limitation concerns the cross-sectional design of our study that does not permit causal inferences between the ERI components and biological parameters. However, most of the individuals experienced highly stable working environments (> 10 years in the same job). Thus, we may assume that our cross-sectional investigation captured working conditions that preceded the medical examination for considerable periods of time. Moreover, half of the participants had their biological measures taken at least 4 weeks apart from completing the questionnaire, in about a quarter of the participants more than 3 months elapsed between psychometric assessment and biomedical measurements. A second limitation arises from the population characteristics. All employees had unrestricted access to health care, the company experienced a relatively stable economic situation, and the skilled workers in this study represented the upper range of the socio-economic status for blue collar work. Our data may, therefore, underestimate the true extent of the effects of imbalance and overcommitment in the general population.

To summarize, we demonstrated that the effort-reward-model is associated with deviations in multiple biological functions, particularly in increased inflammatory activity. Our findings specifically support the interaction hypothesis of the ERI / overcommitment model by showing that indicators of allostatic load and the metabolic syndrome are more profoundly altered when the effect of effort-reward-imbalance is aggravated by a high degree of overcommitment to work.

5.4 Study IV: Testing the factorial structure of the current ERI model – a structural equation modelling approach

ABSTRACT

Background: Several longitudinal studies have related the Effort-Reward-Imbalance Model (ERI) as an independent predictor for cardiovascular disease and other adverse health outcomes. There is a paucity of studies analyzing the factorial structure underlying the key concepts of the current ERI model (Siegrist, 1999).

Objectives: We aimed (1) to test the factorial validity of the core concepts effort, reward, and overcommitment and (2) to test the model for construct validity in terms of a correlation with health related quality of life (SF12 questionnaire).

Methods: The study population comprised 1553 employees from airplane manufacturing industry in Southern Germany. Employing structural equation modelling, four alternative models were fitted.

Results: A confirmatory structural equation model supported the factorial validity of a model with effort and reward subscales as well as a model encompassing the full theory (including overcommitment). A three-factor structural model corroborated the theoretical concept that there are three different types of rewards (esteem, security, money). However, the model fit substantially improved using three new subscales, which differentially assigned items of reward as compared to the original conceptualization (delta chi-square = 774, df = 3, $p < 0.001$) providing excellent fit (GFI = 0.95, CFI = 0.93, RMSEA = 0.57). The new subscales are labelled: esteem, security, and gratification. A hypothesized relation of effort, reward, and overcommitment with health related quality of life could be confirmed.

Conclusion: Using revised subscales for the reward component, the observed data from a large sample of industrial employees confirms the factorial structure of the current ERI-overcommitment model.

Keywords: Effort-reward-imbalance, structural equity modelling, validity.

6 GENERAL DISCUSSION

In the four studies presented, specific findings of the recent effort-reward-imbalance model were elucidated. In this chapter the findings are discussed from a theoretical and practical point of view. The discussion first summarizes briefly the results obtained in studies 1-3 and reflects on the research approach itself. Subsequent theoretical and practical implications of the results are discussed. The thesis concludes with an outline of possible directions of future research while suggesting options to refine the ERI model concerning effort-reward-comparisons, the nature of 'overcommitment', and the structure of reward.

6.1 Summary of empirical findings

Since its introduction by Siegrist in 1986, the ERI model has become a widely used framework for examining job characteristics and health (van Vegchel, de Jonge, Bosma et al., 2004). The model allows the derivation of the following three hypotheses (Siegrist, 2002b): (1) The mismatch between high effort and low reward (non-reciprocity) produces adverse health effects (The extrinsic ERI hypothesis); (2) a high level of personal commitment (overcommitment) increases the risk of reduced health (The intrinsic overcommitment hypothesis); and, (3) the relatively highest risks of reduced health are expected in people who are characterized by conditions (1) and (2) (The interaction hypothesis). The purpose of this thesis was to the test these hypotheses in relation to psychological as well as biological variables.

Study I

Study I was based on a stratified random sample of 642 employees from the manufacturing industry and revealed a strong and independent association between overcommitment and vital exhaustion, an immediate precursor of coronary heart disease events (Appels, Mulder, van 't Hof, Jenkins, van Houtem, & Tan, 1987; Kop, Appels, Mendes de Leon et al., 1994) and a long term risk factor for cardiovascular disease (Cole, Kawachi, Sesso et al., 1999). Vital exhaustion was assessed with the 9-item shortened Maastricht Exhaustion Questionnaire (Appels, Hoppener, & Mulder, 1987). In reference to situational workplace conditions, only effort-reward-imbalance, decision latitude and adverse physical conditions correlated moderately with vital exhaustion. Other work characteristics as assessed by the SALSA questionnaire (such as wholeness of work tasks, task variety, qualification potential, extent of participation, social support of co-workers or supervisor) appear to have low significance for vital exhaustion. Furthermore, vital exhaustion was associated with depression and Type D personality.

Regarding the model's hypotheses, these results confirm the intrinsic overcommitment hypothesis, indicating that a high level of personal commitment (overcommitment) increases the risk of adverse health effects (Siegrist, 2002b). This study demonstrated that vital exhaustion is a further criterion of well-being that can predicted by the model. This finding corresponds with previous studies of the predictive validity of the model for psychosomatic health (de Jonge, Bosma, Peter et al., 2000; Joksimovic, Starke, v d Knesebeck et al., 2002; Kuper, Singh-Manoux, Siegrist et al., 2002; Ostry, Kelly, Demers et al., 2003; Stansfeld, Bosma, Hemingway et al., 1998). Importantly, overcommitment as a personal characteristic had higher predictive power for vital exhaustion than effort-reward-imbalance or any other work characteristic such as decision latitude and adverse physical conditions. In a recent study based on the same population (Schnorpfeil, Noll, Wirtz et al., 2002), associations between vital exhaustion and five SALSA subscales were found in a multivariate regression model that explained about 30% of variance in vital exhaustion scores. When entering the ERI model in a multivariate regression model similar to Schnorpfeil (Schnorpfeil, Noll, Wirtz et al., 2002), only two SALSA subscales remained, namely: decision latitude and adverse physical conditions. With regard to economical screening, it can be argued, that the OC and the ERI model extracts more information than is covered by the 52-item SALSA questionnaire. Even social support, a resource at the workplace that has often been described as a buffer for he negative effects of work stressors, was not retained in the final multivariable model. The notion of the importance of overcommitment has implications for work place redesign that will be discussed in chapter 7.3.2 more detailed.

Study II

Study II showed that employees reporting a mismatch between their efforts and occupational rewards showed lower health-related quality of life, a pronounced risk of sleeping problems, vital exhaustion, and depressed mood, compared to people reporting no high costs/low gain conditions. This finding based on data from 1894 employees of the manufacturing industry corroborate previous investigations in identifying high effort-reward-imbalance status at work as a risk constellation for employees' health and well-being (extrinsic ERI hypothesis) (de Jonge, Bosma, Peter et al., 2000; Godin & Kittel, 2004) (Joksimovic, Starke, v d Knesebeck et al., 2002; Niedhammer, Tek, Starke et al., 2004; Pikhart, Bobak, Pajak et al., 2004; Stansfeld, Bosma, Hemingway et al., 1998; Tsutsumi, Kayaba, Theorell et al., 2001). Furthermore, the results confirm the intrinsic overcommitment hypothesis of the ERI model demonstrating that high overcommitment has an impact on health indicators similar to that of effort-reward imbalance. It is notable that the third prediction derived from the model that individual differences in overcommitment is a contributory factor in aggravating the effect of effort-reward-imbalance could clearly be confirmed. Highly overcommited employees dealing with high effort and low reward conditions are at the highest risk of reporting the most unfavourable health status in terms of vital exhaustion, health-related quality of life, depressed mood, and sleep problems.

To date there has been a paucity of data concerning the interaction hypothesis. Just a few studies examining the relationship between the ERI model and psychosomatic health complaints (three studies) and well-being (four studies) have been included in a recent review (van Vegchel, de Jonge, Bosma et al., 2004). Of these, about half of the studies reported increased risks for psychosomatic complaints or reduced well-being in overcommited employees under high ERI conditions as compared to low overcommited employees. To better understand this inconsistency in findings, this study aimed to fill this gap with respect to the interaction of overcommitment by investigating a large sample of industrial workers using a range of established indicators of health and well-being. The results found in this large sample give further support to the interaction hypothesis. However, due to the still limited number of studies regarding this prediction of the model, the moderating effect of overcommitment requires further elucidation. One explanation of the inconsistency of results might be the different operationalization of "overcommitment". For example, (Bosma, Peter, Siegrist et al., 1998) and (Kuper, Singh-Manoux, Siegrist et al., 2002) applied a proxy measure of overcommitment using a single item, although it is widely accepted that questionnaire measurements should comprise more than a single item, e.g. (Bortz & Döring, 2002) because the use of multiple items in assessing the construct of interest acts to reduce measurement errors and thereby increases the reliability. Thus, use the full measurement of the ERI model that has been validated in different studies is recommended (van Vegchel, de Jonge, Bosma et al., 2004).

The theoretical consequences of the reported findings that clearly support the interaction hypothesis and the practical implications regarding work place redesign will be discussed in chapter 7.3 more detailed.

Study III

Study III was based on data of 1553 healthy employees of the manufacturing industry. The aim was to examine the relationship between effort-reward-imbalance and overcommitment with allostatic load, a concept that reflects the cumulative wear and tear of the organism resulting from repetitive and chronic adaptation to stressful conditions (McEwen, 1998c, 1998b). The study demonstrated that under conditions of high imbalance and high overcommitment several indicators of allostatic load show adverse deviations: Waist-to hip ratio, diastolic blood pressure, LDL cholesterol, leukocytes, CRP, albumin and epinephrine. According to the ERI model, the results confirm the interaction hypothesis in that the interaction of high overcommitment and high effort-reward-imbalance produces the most adverse health effects in terms of allostatic load.

In general, this finding provides further support to the accumulating evidence that chronic job stress is accompanied by profound changes across many biological systems (Belkic, Schnall, Landsbergis et al., 2000). The results suggest that the interaction of high overcommitment and high effort-reward-imbalance may be associated with sustained sympathetic nervous system stimulation as evidenced by increased diurnal catecholamine secretion, and increased inflammation, indicated by higher plasma levels of C-reactive protein and higher white blood cell counts. In contrast to previous studies (Siegrist, Peter, Cremer et al., 1997) we found a decrease in fibrinogen-levels under high imbalance conditions when data were controlled for the confounders like age, gender, alcohol intake, smoking, and physical activity. Overcommitment appeared to aggravate the changes observed with high imbalance alone. Importantly, under conditions of reciprocity (no imbalance), overcommitment showed no impact on allostatic indices.

The finding of altered over-night secretion of catecholamine and parameters indicating aroused immune reactivity suggests the involvement of the sympathetic and parasympathetic nervous system in response to psychological burden at work (Tracey, 2002). The data corroborate previous findings that the ERI model predicts increased diastolic blood pressure (Peter, Alfredsson, Hammar et al., 1998; Peter & Siegrist, 1997; Vrijkotte, van Doornen, & de Geus, 2000). As has previously been shown for effort-reward-imbalance (Peter, Alfredsson, Hammar et al., 1998; Siegrist, Peter, Cremer et al., 1997), we found increased LDL cholesterol levels associated with adverse effort-reward-imbalance and overcommitment. However, the study failed to replicate earlier findings of elevated fibrinogen levels in subjects with job strain (Kittel, Leynen, Stam et al., 2002; Tsutsumi, Theorell, Hallqvist, Reuterwall, & de Faire, 1999) and effort-reward imbalance (Vrijkotte, van Doornen, & de Geus, 1999).

The pathophysiological mechanisms through which effort-reward-imbalance or overcommitment might increase the risk for future coronary events are largely unknown. Although the general understanding of psychobiological phenomena has advanced, many missing explanatory links remain. For interventions based on the effort-reward-imbalance model, it is important to note that most indicators of allostatic load represent risk factors for later diseases. These physiological markers can be in part easily assessed in a standardized medical check-up, and could be used as early warning signs in the future. Further prospective studies have to demonstrate what pathophysiological changes accompany high effort reward / overcommitment conditions. This study is the first attempt to examine those relationships, and it could be speculated – while recognizing the preliminary nature of the findings – that monitoring of allostatic load may serve as useful and valid screening for identifying employees at risk.

6.2 Discussion of the research approach

This chapter presents four major limitations regarding the research approach that have to be critically discussed.

6.2.1 Reliability and validity of measures

First, an important methodological problem concerns, in general, self-report measurements as used in the first and second study. For many years, occupational stress research has been criticized for its reliance on self-report methodologies, in particular questionnaires, to collect information about both dependent and independent variables (Kasl, 1987). There has been concern about the construct validity of self-report measures, because both theory and research indicate that self-report responses are a product of psychological, sociological, linguistic, experimental, and contextual variable, which have nothing to do with the variables of interest (Harrison, McLaughlin, & Coalter, 1996). Because of influences other that item content, it has been pointed out that it is never precisely clear what is being measured (Paulhaus, 1991). As relevant confounders that constrain the explanatory power of self-report data the following factors are discussed in literature.

Response distortions

Acquiescence response style (i.e., tendency to response positively independently from the content of the item, negative affectivity (i.e., tendency to report a high level of negative emotions even in the absence of objective stressors), and social desirability (i.e., tendency to produce answers which one believes more social desirable than the truthful answer) are problematic because of their potential contaminating influence on the relationship between variables, including masking and spurious associations (Bortz & Döring, 2002). To minimize these sources of error, several strategies are recommended: adjustment for a specific response style (negative affectivity), repeated measurement, and different techniques of data collection (e.g. computer assisted interview) (Siegrist, Starke, Chandola et al., 2004).

Method variance

Several researchers have expressed concern over the extent to which relationships between variables may be inflated by method variance when data are obtained from a single source (Tepper & Tepper, 1993). Investigations of multitrait-multimethod matrices using structural modeling have demonstrated that method variance accounts for a substantial proportion of shared variance in studies of job satisfaction (Harvey, Billings, & Nilan, 1985), job characteristics (Glick, Jenkins, & Gupta, 1986), and performance (Vance, Coovert, MacCallum, & Hedge, 1989). The first and the second of the reported studies share this problem as it is not easy to determine what is the explaining and what is the criterion variable. For that reason, the inclusion of different measurements such as methods for evaluating the working conditions is advisable (Schüpbach, 1996), or reports by other observers, such as peers or supervisors (Resch, 2002; Ulich, 2001). The use of objective measures (Kasl, 1987) is also preferable, as in study III, where self-reported data obtained by psychological questionnaires were supplemented with objective data obtained by physiological or biological measurements. This approach enhances the interpretation of causal relationships because these data are free from response bias. The disadvantage, however, is that objective measures may underestimate associations between variables (Frese & Zapf, 1988) and may fail to capture a conceptually subjective experience or a construct that is essentially perceptual.

Reliability and validity

The usefulness of data is to a large extent dependent on the psychometric properties of the instruments used in research, in particular their reliability. Reliability refers to the reproducibility of the measurement. Validity refers to the extent to which an instrument measures what it purports to measure (and not something else). Construct validity reflects the degree to which an instrument captures the hypothetical qualities or traits it was designed to measure (Bortz & Döring, 2002).

In reference to the self-report measurements, the reliability (consistency) of the scales could be confirmed in the investigated study population. The reliability (internal consistency) of the applied scales where in the range of acceptable to very high. That supports the assumption that the scales had been validated accurately by their developers. However, the validity of the self-report data used in this study is not a priori guaranteed. For example, study I and II suggest there is considerable overlap between the concepts of overcommitment, depression, Type D personality, and vital exhaustion. As discussed under the topic of shared method variance, it can not be clearly decided if this overlap is due to the same method, response distortions (excluding negative affectivity, which was accounted for in both studies), or common features of the different constructs. For construct validity, however, it is crucial to know what, for example, the scale overcommitment exactly measures. The occupational stress research is of course interested in revealing cause-and-effect relationships, and the ERI model postulates that overcommitment is the person-specific pre-requisite for adverse health effects, not an indicator of burden and strain produced by the working conditions.

In the case of the measurement of allostatic load, there is reason to acknowledge criticism concerning reliability. The primary mediators (such as blood pressure, glucocorticoids, catecholamines, DHEA, and cytokines) are dynamic systems that change quickly over the course of time. Plasma levels are highly influenced by a wide range of variables such as diurnal cycles, exercise, allergies, sleep deprivation, and persistence of viral and other infections that exacerbate the existing allostatic state, for example, (Borish, Schmaling, DiClementi, Streib, Negri, & Jones, 1998; Cannon, Angel, Ball, Abad, Fagioli, & Komaroff, 1999; Kavelaars, Kuis, Knook, Sinnema, & Heijnen, 2000; Moldofsky, 1995). For this reason, a single one-point measurement as used in study III is highly susceptible to random errors, and it is possible that the reliability of the obtained data is limited. Consequently, repetitive assessment of the allostatic load indices would have been desirable – a condition that was unrealizable in this project with more than 1500 participants. Such repeated measures design should (1) encompass multiple physiologic measurements over longer time intervals (Myrtek, Fichtler, Strittmatter, & Brugner, 1999) and (2) include a multi-method approach with physiological, psychological, and behavioral data (Semmer & Mohr, 2001). On the subject of the validity of allostatic load, the components of allostatic load used in this thesis are debatable. McEwen at al. stressed that the allostatic load parameters were not originally organized and categorized with regard to their position in the cascade of events from allostasis to allostatic load (McEwen & Seeman, 1999). Moreover, there was no suggested framework for relating measures to specific disease outcomes or for the classification of newly added parameters. There is also a particular need to include parameters related to other pathways involved in the pathogenesis of e.g. cardiovascular disease, such as fibrinogen (von Kanel & Dimsdale, 2003a).

6.2.2 Design and study population

The primary interest in occupational stress research is to determine causal relationships. It is generally accepted that longitudinal designs are suitable for showing causal relationships, because they overcome problems of reversed causation and third variables (e.g., negative affectivity) (Zapf, Dormann, & Frese, 1996). However, about 90% of occupational stress research is performed with cross-sectional studies (Zapf, Dormann, & Frese, 1996). As is the case in the reported studies in this thesis, the most serious limitation of cross-sectional studies concerns the issue that they do not permit the interpretation of causality, for example, between the ERI components and the psychological and biological criterions. When associations between a psychosocial variable and an outcome variable have been found, it can always be argued that the real explanation might be a confounding variable (e.g. personality). As elaborated above, certain personality traits might increase the likelihood that participants who complain about adverse life conditions are also more likely to complain about work and about health, and hence trivial associations will arise (Theorell, 2003). For example, the data from the first study demonstrate a considerable overlap between the constructs vital exhaustion, depression and Type D personality. It is this problem of shared variance between the explaining and criterion variables that further aggravates the difficulty encountered in distinguishing between cause and effect.

According to the study sample, the issue of generalization has to be viewed with some caution. The study took place in one country and in one group of employees (skilled workers in airplane manufacturing industry) who represent the upper range of the socio-economic status for blue collar work. All employees had unrestricted access to health care, and the company experienced a relatively stable economic situation. The majority of the study population was male. Future studies have to elucidate the effects of effort-reward-imbalance and overcommitment for woman.

However, it can be reasonably argued, that the results support the predictive validity of the ERI model as reported from previous investigations in different countries and different populations.

The questions that emerge from the present studies include the assessment of changes in the self-reported health outcomes and allostatic load scores that during the course of or following interventions in the work environment. Carefully controlled interventions aimed at improving the balance between effort at work and rewards received are theoretically desirable in order to reduce the risk of adverse health outcomes and to confirm a cause and effect relationship. Unfortunately, there have been just two intervention study published to date (Aust, Peter, & Siegrist, 1997; Irie, Tsutsumi, & Kobayashi, 2003), although intervention studies are the best way of gaining insight into the practical value of the ERI model. This issue calls, again, for longitudinal research in which objective amelioration of work conditions is investigated in relation to self-reported health and biological health status. Thus, not only solutions concerning the individual person (stress management training) but also changes of the psychosocial work environment (like redesign of jobs) must be the main focus of intervention research.

6.3 Implications of the findings

In this chapter, a number of implications of the results are presented.

6.3.1 Theoretical implications

Three consequences emerge from the data reported here: First, there is further evidence that high effort-reward-imbalance is a critical working condition that has an impact on employee's self-reported and biological health. Second, there is much reason to assume that individual differences in overcommitment contribute also to different health outcomes in self-reported health, such as vital exhaustion, health-related quality of life, depressed mood, and sleep complaints. Third, there are risk constellations of high effort-reward-imbalance and high overcommitment that impact on self-reported health and biological health status. This constellation is the most potent risk factor for a number of psychological states that have been associated with cardiovascular disease. Due to relatively marginal secondary evidence from other sources concerning this interaction hypothesis, the most important point deriving from our findings is that poor well-being and health is a critical factor that has its roots in underlying environmental characteristics (i.e. effort-reward-imbalance) and personal characteristics (i.e. overcommitment). This is in line with the interactionist's view of the relationship of work and health. Thus, it can be summarized that the studies reported here have confirmed the predictions of the ERI model. Before the practical implication of this finding is discussed, it should be noted, however, that future studies have to confirm these findings, particularly the interaction hypothesis, where the empirical basis is in the process of being developed. As recommended by Verghel (van Vegchel, de Jonge, Bosma et al., 2004), future studies should test all three hypothesis in the model by using, for reasons of comparability, the full recommended model and not apply crude or proxy measurements as in previous several studies.

6.3.2 Practical implications

For practical purposes such as work place (re)design or health management in organizations, there are many reasons why it can be assumed that the ERI model, as supported by the reported evidence, is useful in evaluating and designing work-site stress prevention and health promotion programs. Unfortunately, there have been just two intervention studies published to date (Aust, Peter, & Siegrist, 1997; Irie, Tsutsumi, & Kobayashi, 2003), although intervention studies are the best way of improving our understanding of the practical value of the ERI model. In spite of the need for further intervention research, there are a number of arguments that justify interventions based on the effort-reward-imbalance model.

One argument is that stressful conditions at work can be easily measured using the standardized, psychometrically validated ERI questionnaire which has been confirmed over a wide range of occupations and populations with diverse socio-economic profiles (Tsutsumi & Kawakami, 2004). A second argument is that this model allows interventions to be derived from the model at the personal, interpersonal, and at the structural level. Based on the model, one goal of intervention is to restore the balance between effort and reward in the work environment.

At the personal/interpersonal level, in addition to the rather non-specific relaxation techniques, the use of techniques of stress management involving focusing on psychological and interpersonal resources is recommended. Several studies from the behavioral sciences suggest that these techniques need to address cognitions, attitudes and work-related motivations in order to be effective (Grawe, Donati, & Bernauer, 2001). Improved self-observation and perception of arousal, coping with anger and reinforced self-reliance are important elements of this type of intervention. Regarding overcommitment, a certain degree of commitment to work is appreciated by the supervisors' perspective. However, our data suggests that individuals who commit themselves to work demands in a disproportional manner are at increased risk for adverse health outcomes (for example, vital exhaustion). As with stress reduction, a most promising approach to modifying such behavioral patterns is the cognitive-behavioral therapy (Roskies, 1987); the range of application is wide, and current evidence acknowledges their effectiveness (Grawe, Donati, & Bernauer, 2001; van der Klink, Blonk, Schene, & van Dijk, 2001). Preventive interventions might assist employees in adopting more favorable coping patterns when exposed to stressful work circumstances, as well as to reflecting on the ideas and assumptions driving overcommitment.

Improvement of leadership skills among supervisors and superiors is another application of stress prevention at the interpersonal level (Cole & Latham, 1997; Simons & Roberson, 2003; Skarlicki & Folger, 1997). Consistent with ERI-model, this approach particularly emphasizes the awareness of the important role of esteem, fairness in social interaction and distribution of rewards and feedback, and recognition.

Structural measures of work-site health promotion derived from this theoretical approach include the implementation of models of gain-sharing and of non-monitory incentives including options of flexible work time arrangements, comparatively high compensation contingent on performance, tailoring of promotion prospects and status according to achievements, improved job security and further measures of organizational and contractual fairness (Tsutsumi & Kawakami, 2004). It is important to note that the creation of healthy work places produces economic benefits in the long run, in addition to beneficial effects on health and well being, for example, (Ulich, 2001).

Table 5: Suggested approach for redesign of psychosocial work environment based on the effort-reward-imbalance model (adapted from Tsutsumi, 2004;(Zapf & Dormann, 2001)

Extrinsic effort
Even distributions of workload Reduction of long over-time work; secure (sufficient) rests or holidays
Extrinsic reward
Monetary and non-monetary (compensatory) reward Encouraging praise for good work Introduction of additional reward system such as welfare facilities and retirement benefits **Esteem reward** Improved interpersonal relationship and social skills of supervisors/managers **Career opportunity** Clearer distinction of promotional levels Appropriate training for career development **Other organizational system relevant to reward (target dimensions)** Better information (sense of fairness) Assessment of an employee's performance, with informed consent (sense of fairness) Developing social support at and beyond the workplace (esteem and buffering of effort-reward-imbalance) Mentoring system (esteem and career opportunity)

6.4 Directions for future research

In this section, remaining questions and opportunites for future research are outlined.

6.4.1 First refinement: Social comparisons

The effort-reward-imbalance model influenced the research on occupational stress during the last ten years. This development is in line with a growing number of publications concerning fairness/reciprocity in work and organizational psychology. Indeed, 'organizational justice' or 'equity' (Cropanzano & Greenberg, 1997) is a well investigated construct, for which the distinction between different dimensions has been suggested (Colquitt, 2001; Colquitt, Conlon, Wesson, Porter, & Ng, 2001): distributive justice, interactional justice, and procedural justice. Distributive justice concerns the fairness of the employee's outcomes relative to a reference group. Interactional justice concerns (a) the degree to which employees are treated with dignity and respect (interpersonal justice) and (b) the importance of conveying information concerning how outcomes are determined (informational justice). Procedural justice refers to the extent to which decision-making procedures allow participation by affected employees. The reward paradigm in the effort-reward-imbalance model addresses the issue of distributive justice (Siegrist, 2002b), whereas job control is more closely related to procedural justice (Theorell, 2003). Perceived justice is associated with several organizational outcomes, such as performance and job satisfaction (Colquitt, Conlon, Wesson et al., 2001), and perceived low organizational justice has now drawn growing attention as an important risk factor to the health of employees (Elovainio, Kivimaki, & Helkama, 2001; Elovainio, Kivimaki, & Vahtera, 2002; Kivimaki, Elovainio, Vahtera, & Ferrie, 2003; Kivimaki, Elovainio, Vahtera, Virtanen, & Stansfeld, 2003). For example, Elovainio et al (Elovainio, Kivimaki, & Helkama, 2001) showed that the effect of job control on psychological strain symptoms was mediated by justice evaluations. It appears that the two lines of research of effort-reward-imbalance and equity can be integrated in a more synergistic way, hereby raising challenging new research questions.

One issue concerning distributive justice or effort-reward-imbalance is discussed here in more detail. From a theoretical point of view it is significant that the evaluation of an exchange situation as 'fair' or 'unfair' depends on a number of factors. In the history of work and organizational psychology, theories can be found that specify the conditions of reciprocity (Ulich, 2001). For example the equity theory as proposed by Adams (Adams, 1963) (Adams, 1965) conceptualizes the working situation as an exchange relation: The employee offers labor, and in return receives material and / or immaterial rewards from the employer. If the employee judges the exchange (ratio) as fair, he or she experiences a psychological state of balance that results in contentment (Adams, 1965). Whether the ratio between efforts and reward is subjectively judged as fair or unfair depends on the perception of the corresponding exchange relation in comparison to others (persons and groups). In other words, the experience of satisfaction or dissatisfaction with the working situation is the result of comparison processes, during the course of which advantages and disadvantages of demands and rewards are weighted against each other. If the discrepancy between efforts and rewards is slight, the employee will attempt to reappraise the perceived advantages and disadvantages in order to minimize the experienced discrepancy. If this is impossible or the experienced discrepancy is too large, the employee will seek a solution either by an active variation of the situation or by psychological adaptation. This may be achieved by reducing either effort or commitment. This can be accomplished by cutting back performance, "flight out of the field" through absenteeism, or prolonged unpaid leave or leaving the work place, or by changing the reference groups.

The specific emphasis of Adams' theory appears to be that the model uses, on the one hand, economical assumptions, hereby grasping the working situation as an exchange situation like Siegrist (Siegrist, 1996). On the other hand, the theory emphasizes the relevance of the social comparison for the perception and judgment of a situation as fair or unfair. Only when considering the economical exchange situation in conjunction with the aspect of social comparison does it become at least in part explicable why the 'relative' quantity of rewards in comparison to peers appears to be more important than the absolute quantity. According to Adams, Pritchard (Pritchard, 1969) has made important supplements that can also be related to the ERI model proposed by Siegrist (Siegrist, 1996) and can be regarded as forming the basis for further research: (a) In each case one could not know a priori whether aspects of the exchange relation such as responsibility is experienced more in terms of effort or of reward; (2) it is not clear by what means the choice of the reference group is defined; (3) there may be individual differences in the appraisal of fairness; and (4) judgment of an exchange situation as fair or unfair may also be made on the basis of internal standards.

6.4.2 Second refinement: What is 'overcommitment'?

What is overcommitment? Overcommitment has been defined as a personality trait that is characterized by the inability to disengage oneself cognitively, emotionally, and behaviorally from work obligations. It has been suggested that overcommitment overlaps with the Type A coronary behavior pattern (Vrijkotte, van Doornen, & de Geus, 1999). Two decades ago, the National Institutes of Health declared Type A behavior as an independent risk factor for coronary heart disease on the basis of early positive findings in the Framingham Study (Haynes, Feinleib, & Kannel, 1980) and the Western Collaborative Group Study. The latter reported that Type A behavior was associated with a 2-fold increased risk of CAD and a 5-fold increased risk of recurrent MI over an 8.5 year follow up (Rosenman, Brand, Jenkins, Friedman, Straus, & Wurm, 1975). Type A individuals were characterized by hard driving and competitive behavior, a potential for hostility, and exaggerated commitment to work (Hemingway & Marmot, 1999; Rozanski, Blumenthal, & Kaplan, 1999). However, the subsequent publication of negative findings dampened the enthusiasm for Type A research. Several studies that tried to link Type A or hostility to coronary heart disease failed to show an increased risk (Rozanski, Blumenthal, & Kaplan, 1999). According to a recent review, there remains little evidence that Type A personality is an independent risk factor for CAD (Hemingway & Marmot, 1999). Due to this lack of consistency, several confounders such as social support (Blumenthal, Burg, Barefoot, Williams, Haney, & Zimet, 1987) have been suggested. Furthermore, a refinement of the Type A construct has been claimed, and it was suggested that only the hostility component of Type A behavior might be of aetiological relevance (Hearn, Murray, & Luepker, 1989; Kawachi, Sparrow, Kubzansky, Spiro, Vokonas, & Weiss, 1998). Hostility is a broad psychological construct that encompasses negative orientations toward interpersonal relationships, and includes such traits as anger, cynism, and mistrust. To date, the results of about ten prognostic studies assessing the relationship between hostility and CAD in healthy subjects have revealed significant associations; but the effects are too small to be of clinical significance (Myrtek, 2000). A conclusion about the 'toxicity' of other personality characteristics that were also discussed as potential risk factors for CAD is still open. Candidates are Type D personality (Denollet & Brutsaert, 1998) (Denollet, 2000) or social dominance (Houston, Babyak, Chesney, Black, & Ragland, 1997). These personality traits have not been widely investigated, and their criterion and prognostic validity is not fully understood.

Overcommitment as a concept that overlaps with the Type A behavior pattern might evolve as a possible pathogenic component with prognostic relevance for CAD, for review see (van Vegchel, de Jonge, Bosma et al., 2004). However, there is still a theoretical lack of understanding about the nature of overcommitment. With respect to content, item 1 ("I get easily overwhelmed by time pressures at work") describes a feeling of time pressure, whereas it is unclear if this is due to work characteristics or subjective perception. Items 2, 3, 5, and 6 ("I start thinking about work problems as soon as I get up in the morning"; "When I get home, I can easily relax and forget all about work."; "Work is usually still on my mind when I go to bed."; "If I put off something that needs to be done today, I'll have troubles sleeping at night.") reflect the subjective perception of work related burdens. Item 4 ("People close to me say that I sacrifice too much for my job.") could be described as an inability to withdraw from work, but could also reflect competitive behavior, exaggerated commitment to work, or a high motivation for achievement. Beside the criterion of face validity, further studies should elucidate the external validity of overcommitment concerning alternative psychological constructs. Study I points in this direction by demonstrating that overcommitment shows some overlap with type D personality, depression, and vital exhaustion. A further issue is whether overcommitment is a trait-like affective/motivational behavior that remains relatively stable across different demand situations, or whether overcommitment reflects a psychological state that shows variability depending on the specific context. To answer this question, longitudinal studies with repetitive measurements of overcommitment are required.

6.4.3 Third refinement: Factorial structure of 'reward'?

Since about 2000, the use of a standardized questionnaire by Siegrist and Peter (Siegrist & Peter, 1997) has allowed the accumulation of evidence for the validity and robustness of the effort-reward-imbalance model. Work to validate the scales has been carried out in several study samples, such as the Somstress Study (Belgium), the GAZEL-Cohort study (France), the WOLF-Norrland Study (Sweden), the Whitehall II Study (UK), the Public Transport Employees Study (Germany) (Siegrist, Starke, Chandola et al., 2004) (Hanson, Schaufeli, Vrijkotte et al., 2000). Internal consistency of the scales were satisfactory in all samples (ranged from 0.68 – 0.79), and the factorial structure of the scales 'effort', 'reward' and the short form of 'overcommitment' scale could consistently confirmed (all goodness of fit measures > 0.92) (Siegrist, Starke, Chandola et al., 2004). Regarding the 'effort' scale, a three-factorial structure has been postulated with (a) financial reward, (b) esteem reward, (c) rewards related to promotion prospects (career) and job security. The three dimensions are thought to load on one latent factor reward – an assumption that has also been confirmed in several second-order factor analyses (Siegrist, Starke, Chandola et al., 2004).

In the forth study reported in this thesis, the dimensional structure of the ERI model was tested again, using structural equation modelling. The applied statistical package was AMOS 5. General model fit was evaluated with chi-square statistics and goodness of fit indices (comparative fit index CFI; root mean square error of approximation RMSEA). GFI and AGFI indicate the amount of variance and covariance explained by the model. GFI values ﬄ 0.85 was considered satisfactory. Concurrent model fit was evaluated with chi-square difference tests.

Table 6 summarizes the results of confirmatory factor analyses for the effort and reward scale.

Table 6: Criteria of goodness of fit of the three components of the model (confirmatory factor analysis).

	Model 1	**Model 2**	**Model 3**	**Model 4**
Chi-square (*p*)	1863.07 (0.000)	1140.66 (0.000)	756.03 (0.000)	1796.59 (0.000)
df	118	115	113	224
Chi-square / df	15.79	9.92	6.69	8.02
GFI	.876	.926	.950	.916
AGFI	.839	.901	.932	.896
CFI	.811	.887	.929	.883
RMSEA (95% CI)	.091 (.087-.095)	.071 (.067-.075)	.057 (.053-.061)	.063 (.060-.066)

Generally, the results confirm the factorial validity of a model with effort and reward subscales as well as a model encompassing the comprehensive theory (including overcommitment) (Figure 11, Model 4). All models explained about 84 to 95% of observed variance and covariance (GFI, AGFI). Regarding the effort scale, the model fit based on the assumption of one latent factors with five variables (see Figure 8, Model 1) loading on one effort dimension could be confirmed. Regarding the reward scale, the situation is more complex because of the postulated three-factor structure of reward. As can bee seen from Figure 9, model 2 corroborated the theoretical assumption that three different types of rewards exist. Table 6 indicates that the model fit substantially elevated using three subscales. The model fit was even slightly better when differentially assigned items of reward were used as compared to the original conceptualization (Figure 10, Model 3). In the slightly modified model, gratification also includes respect from supervisors and respect and prestige in general; respect and prestige are included because it can be argued that both correlate strongly with chances of promotion.

Figure 8: Model 1

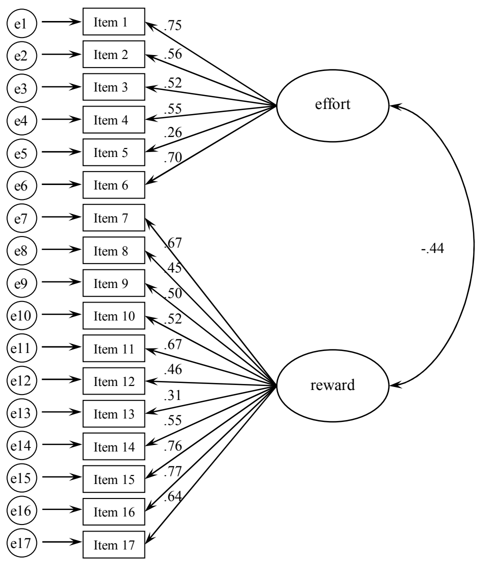


Figure 9: Model 2

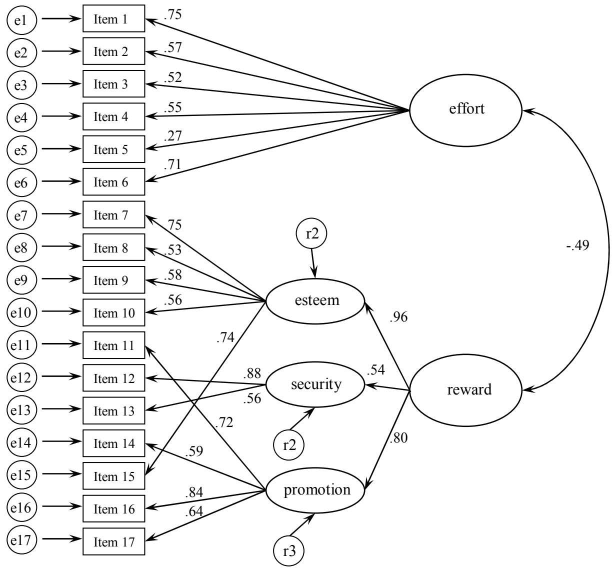


Figure 10: Model 3

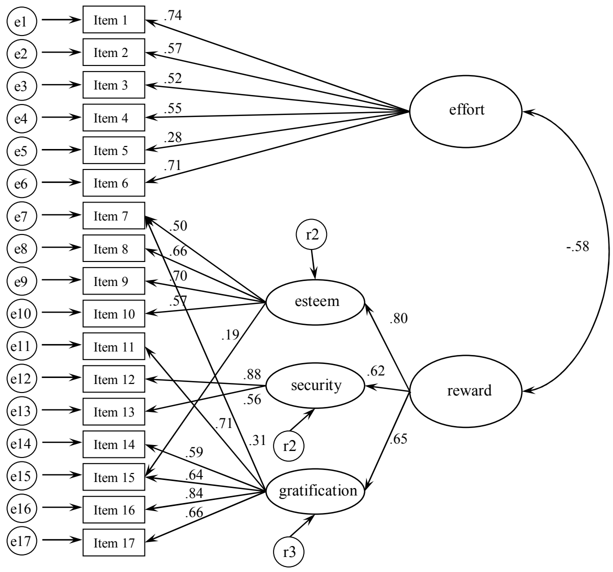
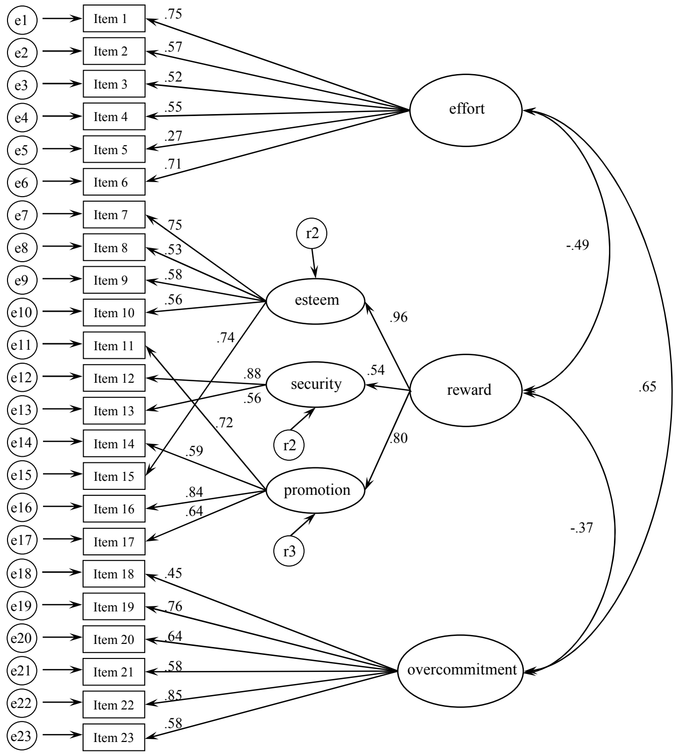


Figure 11: Model 4



In summarizing the findings, the constructs underlying the theoretically effort-reward-imbalance / overcommitment model could be replicated. However, further studies should acknowledge the different reward dimensions and investigate their impact on health outcomes. Besides calculating a holistic effort-reward-imbalance index, it could be interesting to test different kinds of violations of expected reward: violations of self esteem, job security, or of job promotion. The relative importance of the three reward dimensions has yet to be clarified (Tsutsumi & Kawakami, 2004). Investigating what kind of reward 'matters most' to health outcomes could form a fruitful basis for designing and improving interventions aimed at promoting a healthier work environment.

7 CONCLUSIONS

In general, the studies in this thesis demonstrate that the effort-reward-imbalance model provides important measures for the evaluation of adverse working environments. Its predictive validity is high for various psychological health outcomes, such as vital exhaustion, self-reported quality of life, depressed mood, sleep problems, and indicators of allostatic load. The reliability and the factorial validity of the model can be considered as high. Not only do the reported findings generally correspond with previous findings, the new findings also broaden our understanding of the key role played by critical psychological factors in adverse working environments for employees' health.

It is recommended that the ERI is applied as a validated and economical instrument to screen and improve workplace conditions.

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9 APPENDICES

Original items of the Scales measuring effort-reward-imbalance at work (Siegrist, 2002)

Effort scale

1 I have constant time pressure due to a heavy work load.

2 I have many interruptions and disturbances in my job.

3 I have a lot of responsibility in my job.

4 I am often pressured to work overtime.

5 My job is physically demanding.

6 Over the past few years, my job has become more and more demanding

Reward scale

Component esteem

7 I receive the respect I deserve from my supervisors.

8 I receive the respect I deserve from my colleagues.

9 I experience adequate support in difficult situations.

10 I am treated unfairly at work.

15 Considering all my efforts and achievements, I receive the respect and prestige I deserve at work.

Component job promotion

11 My job promotion prospects are poor.

14 My current occupational position adequately reflects my education and training.

16 Considering all my efforts and achievements, my work prospects are adequate.

17 Considering all my efforts and achievements, my salary/income is adequate.

Component job security

12 I have experienced or I expect to experience an undesirable change in my work situation.

13 My job security is poor.

Overcommitment Scale

1 I get easily overwhelmed by time pressures at work.

2 I start thinking about work problems as soon as I get up in the morning.

3 When I get home, I can easily relax and forget all about work.

4 People close to me say I sacrifice too much for my job.

5 Work is usually still on my mind when I go to bed.

6 If I put off something that needs to be done today, I'll have troubles sleeping at night.

10 PUBLICATIONS

This thesis is based on the following original papers and presentations, which will be referred to in the text by their Roman numerals.

Papers

I Preckel D, von Känel R, Kudielka BM, Fischer, JE. Overcommitment is associated with vital exhaustion. International Archives of Occupational and Environmental Health (in press).

II Preckel D, Meinel M, Kudielka BM, Haug HJ, Fischer JE: Effort-reward-imbalance, overcommitment and self-reported health: Is it the interaction that matters most? Journal of Occupational and Organizational Psychology (in press).

III Preckel D., von Känel R, Meinel M, Fischer, JE: The relation of Effort-reward-imbalance and overcommitment to allostatic load (submitted).

Poster

IV Preckel D., Metzenthin P., Kudielka BM, Hanebuth D, Hagemann D, Fischer JE: Testing the factorial structure of the current ERI model – a structural equation modeling approach. Poster presentation on the 63rd Annual Scientific Meeting of the American Psychosomatic Society, Vancouver (CAN).

V Preckel D, von Känel R, Kudielka BM, Fischer, JE (2004): Overcommitment is associated with vital exhaustion. Poster presentation on the 62nd Annual Scientific Meeting of the American Psychosomatic Society, Orlando (USA).

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11 CURRICULUM VITAE

Particulars

Name:	Daniel Preckel
Date of birth:	February 19, 1974
Place of origin:	Münster (Westfalia)
Nationality:	German

Education

1980 – 1984	Primary school in Laer, Germany
1984 – 1993	Secondary school in Borghorst, Germany
1995 – 1997	Undergraduate studies in psychology at the University of Freiburg, Germany
1997 – 2002	Graduate studies in psychology at the University of Freiburg, Germany
2003 – 2005	Research assistant at the Institute for Behavioral Sciences, Swiss Federal Institute of Technology, Zurich, Switzerland
2003 – 2005	Doctorate in psychology at the University of Zurich, Switzerland